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16. ABSTRACT

The principal objective of this study was to document with case studies relationships between site remediation methods, cleanness criteria, and redevelopment land uses.

Sixteen uncontrolled hazardous waste sites were selected for detailed study. For each of these sites, remedial actions have been undertaken or are planned with some upgraded redevlopment of the property in mind. Redevelopments include single- and multi-family residential, recreational, commercial, institutional, and light industrial land uses.

Two distinctly different types of redevelopment efforts were encountered--public-initiated projects and developer-initiated projects. In the case of public-initiated projects (for example, most Superfund sites), immediate concerns for community health are paramount, and site reuse, if any, tends to be incidental to site cleanup. In developer-initiated projects, the developer attempts to recover site cleanup costs through resale of the property. Developers divert into cleanup operations money that would otherwise be used to purchase uncontaminated land.

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RECLAMATION AND REDEVELOPMENT OF CONTAMINATED LAND: VOLUME I. U.S. CASE STUDIES

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs, and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments, and the needs of both large and small businesses in handling their wastes responsibly and economically.

This report, Volume I of a two-volume set, presents information on reclamation and redevelopment of contaminated land in the United States. Case studies describe land use history, nature of the contamination, redevelopment objectives, site remediation, and criteria for cleanup. For further information, please contact the Land Pollution Control Division of the Hazardous Waste Engineering Research Laboratory.

Thomas R. Hauser, Director
Hazardous Waste Engineering Research Laboratory

ABSTRACT

There are numerous cases in the United States where uncontrolled dumping or industrial spills have contaminated properties with hazardous materials (now more than 18,000 sites have been inventoried by U.S. EPA). Since many of these properties are in prime urban locations, issues surrounding the reclamation and redevelopment of contaminated properties have assumed national importance. The principal objective of this study has been to document with case studies relationships between site remediation methods, cleanness criteria, and redevelopment land uses.

After extensive interviews with Federal and State officials in all 50 States, 16 uncontrolled hazardous waste sites were selected for detailed study. For each of these sites, remedial actions have been undertaken or are planned with some upgraded redevelopment of the property in mind. Redevelopments include single- and multi-family residential, recreational, commercial, institutional, and light industrial land uses.

Two distinctly different types of redevelopment efforts were encountered--public-initiated projects and developer-initiated projects. In the case of public-initiated projects (for example, most Superfund sites), immediate concerns for community health are paramount, and site reuse, if any, tends to be incidental to site cleanup.

In the case of developer-initiated projects, the developer attempts to recover site cleanup costs through resale of the property. Thus, he simply diverts into cleanup operations money that would otherwise be used to purchase uncontaminated land. The economic feasibility of a developer-initiated project may depend directly on the standard of cleanness required of a site for a particular redevelopment type. Since property decontamination standards and guidelines have not been formulated for most situations, some confusion exists and hence, developers generally view contaminated site reclamation/redevelopment projects as undesirable ventures.

This report was submitted in partial fulfillment of Contract No. 68-03-3149, 23-1 by Research Triangle Institute under sponsorship of the U.S. Environmental Protection Agency. The report covers a period from May 1, 1983 to May 1, 1985, and work was completed as of June 30, 1985.

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SECTION 1

INTRODUCTION

BACKGROUND

Prior to 1976, few states had regulatory programs for land disposal of hazardous wastes. However, national awareness of hazardous waste problems increased dramatically in the mid to late 1970's as it became evident that mismanagement and indiscriminant dumping of hazardous wastes at many sites had led to the release of toxic materials into the land, water, and air.

Congress responded to the national concern over hazardous wastes by enacting the Resource Conservation and Recovery Act (RCRA) of 1976 and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) better known as Superfund. RCRA is concerned primarily with the proper management and permitting of present and future controlled hazardous waste containment areas. Superfund activities focus on potential hazards posed by uncontrolled hazardous waste sites.

Currently under the CERCLA program, more than 18,000 uncontrolled waste sites are inventoried in EPA's Emergency and Remedial Response Information System (ERRIS). Of these ERRIS sites, 541 have been determined to represent such a critical problem that they have been included on the Superfund National Priority List (NPL) (1). An additional 309 sites have been proposed for inclusion in the NPL (2). Cleanup of these NPL sites is now either under consideration or is underway. The number of sites included on the NPL is expected to grow to between 1,400 and 2,000 during the next two years.

Uncontrolled hazardous waste sites are distributed throughout the U.S. occurring in various geological settings and in urban as well as rural areas. Uncontrolled sites may be operational, inactive, or abandoned. A wide range of chemical wastes has been deposited at uncontrolled land sites, and the extent and severity of the resulting environmental contamination varies greatly across sites.

The extent of remedial action required to protect the public health and welfare is influenced by numerous factors, many of which are site-specific. Some of the important factors are climatic or hydrogeological in nature. Others relate to land surface features such as topography or development that determine exposure routes. The types of chemicals present on-site, the potential for migration, the degree of contamination, extent of the area affected, and the costs of remedial action alternatives are all issues that must be considered as mandated by the National Contingency Plan

(NCP) under CERCLA. Other important issues include the relationship to drinking water sources and population centers, potential social and economic impacts, and the potential for land redevelopment and reuse.

Costs of site remediation vary greatly, ranging from several hundred thousand dollars up to $20 million per site. A 1983 report by the Office of Technology Assessment of the U.S. Congress (OTA) concludes that "to clean up a substantial fraction of the more than 15,000 presently known uncontrolled hazardous sites is likely to cost, in public and private spending, a total of $10 billion to $40 billion" (3). CERCLA funds are intended to be used only for cleanup of uncontrolled sites where no responsible party can be identified, or for advancing funds for cleanup prior to recovery of costs from responsible parties.

There are many uncertainties about the effectiveness of cleanup activities at uncontrolled hazardous waste sites. In addition to the technical risks associated with site remediation, public beliefs and attitudes will also determine in part the success of remediation activities, at least as they pertain to site redevelopment.

A central issue for the planning of any remedial action is the criteria to be used in determining the extent of cleanup required. Acceptable concentration limits that establish the extent of cleanup necessary to protect public health and welfare have not been determined for most toxic substances of concern. The "how-clean-is-clean?" question is often posed in relation to the NCP under CERCLA. Although U.S. EPA has received considerable comment regarding the need for allowable levels of release from sites following remediation, the agency has maintained that the flexibility in the current approach is appropriate because of the site-specific nature of most problems and the need to move ahead with remediation programs in an expeditious fashion.

In view of the large number of uncontrolled hazardous waste sites in the U.S. and the extent of effort required to properly remediate these sites, issues related to uncontrolled hazardous waste site remediation and redevelopment are of national significance. However, because site remediation and reuse are relatively new public concerns, very little information concerning hazardous waste site redevelopment has previously been compiled to describe instances where redevelopment has occurred following site cleanup. This report presents a beginning in this new area.

PURPOSE

The purpose of this report is to document the value and importance of land reuse planning in the design of hazardous waste remediation measures. Major emphasis is placed on presenting the functional relationships among alternatives with respect to site remediation methods, cleanup criteria, and options for reuse. The three main objectives are:

1. To identify and document specific instances where uncontrolled hazardous waste sites have been cleaned up and redeveloped;
2. To assemble information on the criteria that have been used to guide hazardous waste cleanups; and
3. To examine the relationships between site reuse and the extent of remediation or cleanup criteria.

ORGANIZATION

A summary of the project findings and conclusions is provided in Section 2. The approach to the data gathering and findings of a general nature are detailed in Section 3. In Section 4 the available standards and criteria that have been used to guide remedial actions are examined. Section 5, the main section of the report, documents the experience at specific sites where redevelopment has followed cleanup of hazardous waste. The sites presented as case studies in Section 5 were selected from among many that were identified during the course of the project because collectively they illustrate many of the problems and solutions applicable to contaminated land reclamation and redevelopment.

Appendix A lists the U.S. EPA, state office and U.S. Army officials who were contacted during the course of the project and who provided information to the project team. Appendix B consists of tables listing some of the various guidelines that have been used in site assessments and as criteria for site remediation efforts.

SECTION 2

SUMMARY AND CONCLUSIONS

There are many instances in the United States where uncontrolled hazardous waste sites have been or soon will be redeveloped for some upgraded land use. This trend is expected to increase in the future as more sites are remediated. Sites that are redeveloped following hazardous waste cleanups are not easily documented through references to the open literature, for several reasons. First, the brief history of federally-supported waste site redevelopment efforts in this country has not yet resulted in a long list of completed projects. Second, the substantial costs and investment risks associated with hazardous waste site cleanup operations appear to have discouraged developers from attempting to reclaim many contaminated sites. Third, the delays associated with decision-making may stifle redevelopment projects where hazardous wastes are involved. When developers do become involved with an uncontrolled hazardous waste site, they try to perform the necessary remediation to the satisfaction of the regional and local authorities with little publicity if possible.

CASE STUDIES

To serve as case studies to illustrate contaminated land reclamation and development, 16 sites located in nine states were selected and examined in detail. Case study sites include former Department of Defense (DOD) properties, defunct gasification sites, abandoned chemical recovery and drum recycling facilities, a former steel mill, munitions, fertilizer, and pesticide manufacturing sites, a coal tar refinery, a warehouse for chemical storage, and several uncontrolled dump sites. Land reuses at these sites include industrial parks, recreation parks, a hotel and convention complex, single family residences, a public school, residential condominiums, a housing complex for handicapped and elderly, a neighborhood playground, and State offices and facilities. Brief descriptions of the sites examined in the remediation/redevelopment case studies are provided in Table 1.

Six of the land reuse case studies are located in California. Concerns at these sites pertained mainly to potential exposure of persons who might live or work at the site following redevelopment. In most cases, material and soil that were determined by the California Department of Health Services (CDHS) to be hazardous were removed to a permitted disposal facility. All of the California case studies are located near large metropolitan areas.

In Hercules, California, the former site of the Hercules Powder Works which manufactured dynamite and other munitions from 1912 until 1963, three cases of successful redevelopment are documented. A residential

TABLE 1. REDEVELOPMENT SITES SELECTED FOR CASE STUDIES

Site and Reuse Description	Nature of Contamination	Remediation
Bio-Rad Laboratories 175 acres Hercules, CA Reuse: Industrial Park	Formerly used for TNT production by Hercules Powder Works; numerous deteriorating metal drums and soil contaminated with heavy metals (Pb, Zn, Cu, Cd) and explosives.	Drums removed; contaminated soils excavated. More than 1,835 cu m (>2,400 cu yd) of soil and debris removed to a permitted hazardous waste disposal facility.
Hercules Village 50 acres developed by D S Company Hercules, CA Reuse: Residential condominiums	Formerly used as wastewater treatment area by Hercules Powder Works; contaminated with As, Pb, Cr, Zn, DNT, and DNB.	Almost 7,646 cu m (10,000 cu yd) of soil removed to a permitted hazardous waste disposal facility; some residues of DNT and DNB left onsite and covered by more than 3 m (10-12 ft) of clean fill in area restricted from residential development 2-year monitoring program.
Bayside Village 100 acres Developed by Citation Builders Hercules, CA Reuse: Single-family residences and public school	Formerly Hercules Powder Works property. Surface and subsurface soil contained Pb at levels as high as 530 ppm.	All contaminated soil removed.
Bolsa Chica 12.5 acres Mola Development Corporation Huntington Beach, CA Cost of Cleanup: >$5 million Reuse: Residential Condominiums (224 units)	Site of uncontrolled dumping of refinery sludges (>1,529 cu m) prior to 1963; permitted Class III landfill from 1963. Contaminated with acidic petroleum wastes (aliphatic and aromatic hydrocarbons, amines, thiophenes); methane and odor.	All 45,873 cu m (60,000 cu yd) contaminated material removed to a permitted hazardous waste disposal facility.
The Gateway 117 acres Developed by Homart Development Company South San Francisco, CA Reuse: Hotel and Convention Center	Formerly a steel mill and fabrication plant using coal-fired open hearth furnace. Soils contaminated by heavy metals, oils, and acids deposited over 75 years. Localized high concentrations of As, Cr, Zn, Cu, Ni, low pH, and PCB's.	Due to large volume, majority of contaminated materials contained onsite and capped. More than 700 cu m of hazardous material removed to offsite disposal facility.

(continued)

TABLE 1. (Continued)

Site and Reuse Description	Nature of Contamination	Remediation
Kellog Terrace 21 acres Gfeller Development Company Yorba Linda, CA Reuse: Residential Condominiums (224 units)	Site of sand and gravel excavation prior to 1940; uncontrolled dumping of refinery waste and used drilling muds in 1940's. Contaminated from Pb, As, and aliphatic and aromatic hydrocarbons.	7,034 cu m (9,200 cu yd) of contaminated soil and fill removed to a permitted hazardous waste disposal facility.
Annapolis Road Sites Baltimore, MD Cost of Cleanup: >$325,000 Reuse: Maryland Department of Health Office and Storage; Neighborhood Park	Sites used by Chemical Metals Industries, Inc. for recovery of precious metals from waste chemical solutions and printed circuit boards. Large number of leaking drums (corrosive liquids, ammonia- or cyanide-bearing materials, organic solvents); storage tanks, unstable powdered and solid zirconium metal; high levels of Cd in soil. Contaminated groundwater.	More than 1,500 plastic and metal drums removed. Waste oil, water and gasoline pumped from underground tanks. Walls decontaminated by sandblasting. Approximately 91 metric tons (100 tons) of contaminated soil and debris and 175 drums of solids and sludges removed to a permitted hazardous waste disposal facility. Aboveground tanks emptied and removed. Zirconium metal removed.
Miami Drum Site 1 acre Miami, FL Cost of Cleanup: $1.6 million Reuse: Dade County Transit Authority Maintenance Facility	Used for 15 years by Miami Drum Services for drum recycling; 400 to 500 used drums left onsite. Surface and subsurface soils and groundwater contaminated from spills--phenols, heavy metals, oil and grease, and pesticides.	7,335 cu m of hazardous debris and contaminated soil removed to permitted hazardous waste disposal facility. Marginally contaminated soils left in place. Groundwater treated onsite.
Kapkowski Road Site West Area--134 acres East Area--111 acres Elizabeth, NJ Reuse: Future Industrial Park by the Port Authority of New York and New Jersey	Uncontrolled dump site from mid 1950's to 1972. Contamination from waste oil containing PCBs up to 4,800 ppm. Between 1 and 3 million gallons of oil floating on water table and adhering to materials in refuse, primarily in the west area.	Pump out free floating oil from pockets; leave refuse in place. Soils with PCB's greater than 5 ppm to be disposed to a permitted facility if such soil is discovered during excavation for building foundations.

(continued)

TABLE 1. (Continued)

Site and Reuse Description	Nature of Contamination	Remediation
Aidex Pesticide Facility Aidex, Iowa Reuse: To be determined; possibly another pesticide firm	Pesticides in drums and spilled in many areas of the site including metal buildings. A fire occurred at the facility in 1976.	Drums and rusting barrels removed to a permitted hazardous waste disposal facility. Contaminated soil excavated and removed. Remediation still incomplete.
Gas Works Park 20.5 acres Seattle, WA Reuse: Public park	Formerly site of the Seattle Gas Works on Lake Union. Entire peninsula heavily contaminated with residues from gas production, spills, waste materials, and air pollution fallout. Extensive hydrocarbon contamination including polycyclic aromatic hydrocarbons (PAH) associated with coal tars.	Demolition and burial on-site of most of the old gas-works structures. Excavation of specific areas of severely contaminated soil. Special efforts to improve growing conditions at the site. Further remediation efforts needed to insure minimal exposure to park users. Some park areas closed to public. Warning signs posted.
Quendall Terminal 20 acres WA Reuse: Condominums and office buildings	Former site of a Reilley Tar and Chemical Company refinery on Lake Washington. Extensive contamination from coal tar and byproducts. PAH in concentrations as high as 4.8 percent. Benzene, toluene, and xylene are present, and there is groundwater contamination.	System of French drains to divert surface water and a slurry wall to prevent Renton, drainage into the Lake; recover and treat groundwater on-site; Clay cap over entire site. (Proposed remediation strategy).
Boulevard Park Bellingham, WA Reuse: Public park	Former site of a coal gasification plant constructed in 1890. Storage tank on-site still contains product residues. Buried hydrocarbons seeping to surface in some areas. High concentrations of benzo(a)pyrene in exposed coal tar and in contaminated soil.	Remediation activities during park construction not documented. Investigation in 1984 revealed contamination. Warning signs posted.

(continued)

TABLE 1. (Continued)

Site and Reuse Description	Nature of Contamination	Remediation
New York State Electric and Gas Corporation (NYSEG) site 11 acres Plattsburgh, NY Reuse: Recreation Park on the Saranac River	Formerly a coal gasification plant operated by NYSEG. Soil and sediment from the Saranac River contaminated with coal tar leached from unlined coal tar ponds.	Subsurface migration of tar from original disposal ponds arrested by soil-bentonite slurry wall. Contaminated sediment from river bed excavated and removed to containment area surrounded by slurry wall. Containment area capped with Hypalon liner. Cement-bentonite cutoff wall constructed to prevent migration of uncontained coal tar into the river.
Frankford Arsenal Site 110 acres to be developed by Shetland Properties; 18 acres to be developed by Pennsylvania State Fish Commission Philadephia, PA Cost of cleanup: $8 million Reuse: Regional Park and Marina and Light Industrial Development	Formerly used by the U.S. Army for munitions manufacture and research development of armaments. Low-level radiological contamination in buildings, deposits of explosive/pyrotechnic residues, unexploded ordnance, inorganic chemical residues in buildings and underground waste discharge system.	Explosives residues destroyed. Radiological and heavy metal contamination removed from the site.
The Courtyard Developed by Vermont Associates Winooski, VT Cost of Cleanup: $15,000 Reuse: Housing Project for the Handicapped and Elderly	Warehouse used for storage of industrial chemicals; formerly occupied by a silk-screening firm. Approximately 5.66 cu m (200 cu ft) of solid chemical wastes beneath wood flooring; traces of organic solvents, oil.	Underground tanks emptied; 84 metric tons (93 tons) of solid inorganic waste and contaminated wood flooring removed to a permitted hazardous waste disposal facility. Vapor barrier installed and covered by 4 inches of concrete.

subdivision (single family homes) with a public school was developed as Bayside Village on the southernmost portion of the former Hercules property following a very stringent remediation effort in 1981. Cleanup operations on a second tract of the property were completed in 1983 by Bio-Rad Laboratories, and an industrial park is currently being developed there. Another tract of 50 acres was also cleaned up in 1983 to make way for the residential condominiums known as Hercules Village.

Residential condominiums also have been developed at former uncontrolled hazardous waste sites in Huntington Beach and Yorba Linda, California. Contamination at these sites stemmed from dumping of refinery wastes including both acid and alkali sludges. The removal operations at these sites were complicated by extensive foul odors from sulfur compounds that were released from the petroleum waste during excavation. All waste material and contaminated soil were removed to a landfill permitted to receive hazardous waste.

In South San Francisco a former steel mill and fabrication plant site has been redeveloped as "The Gateway," a hotel and convention center complex. The remediation agreement stipulated that the location of the contaminated soils be clearly designated on a site map and that these areas not be excavated or substantially disturbed in the future without CDHS approval. A deed restriction was negotiated as a way of enforcing these provisions over time.

The Dade County Transit Authority has plans for a maintenance facility at the former Miami Drum Services site in Miami, Florida. The contamination resulting from the drum recycling operation caused major concern because the Biscayne Aquifer which supplies the drinking water for Dade County lies only one meter below the natural ground surface at the site. Although total metal concentrations in the soil were used as guidance in the initial excavations, final excavations were guided by the results of chemical tests together with engineering and scientific judgment.

The former Chemical Metals Industries, Inc. site in Baltimore, Maryland, also presented an immediate potential hazard. In this case, the major concerns included imminent threat of fire or explosion in the residential neighborhood due to the chemical incompatibilities of the materials present and to the potential hazard posed by runoff from the site. Following a remedial action under CERCLA, the site now serves as a neighborhood playground and as the location for a state office building.

In Winooski, Vermont, a warehouse formerly occupied by a silk-screening firm and used for storing a variety of chemicals has been rennovated to provide housing for elderly and handicapped persons. Remedial action at the site involved removal of piles of solid chemical wastes that had filtered through cracks and holes in the wooden flooring.

Remediation and redevelopment at the Kapkowski Road site in Newark, New Jersey, are underway currently by the Port Authority of New York and New Jersey. Pockets of PCB-laden oil are being eliminated through a series of oil recovery wells. The site had been used for many years as a dump, receiving solid refuse and waste oil. The property, adjacent to the Newark Airport, is a prime location for development as an industrial park. The extent of the remediation effort that will be performed will be determined when excavation begins for building. During construction if soils are encountered that contain more than 5 ppm of PCB's, the contaminated material will be removed to a permitted disposal facility.

A local Industrial Foundation in Glenwood, Iowa, is currently seeking a tenant for a site formerly occupied by a pesticide plant. An extensive cleanup at the site was carried out following a fire in 1979.

At Plattsburgh, New York, a recreation park now occupies a site where a coal gas generating plant operated from 1896 until 1960. Large quantities of coal tars stored in unlined ponds resulted in the contamination. The site remediation consists of containment onsite and a cement-bentonite partial cutoff wall to arrest any further migration of the contamination into the Saranac River. In allowing the material to remain onsite, the New York State Department of Environmental Conservation (NYSDEC) has imposed certain restrictions to development.

Two other coal gasification sites located in Seattle and Bellingham, Washington are now used as recreation parks. The extent of the remediation efforts at these sites is not documented because at the time of the redevelopment, hazardous wastes were not of much concern. Recent investigations at both sites have revealed the presence of high levels of polycyclic aromatic hydrocarbons from coal tar.

Among the U.S. Department of Defense (DOD) sites where remediation and redevelopment have been undertaken is the Frankford Arsenal site located in eastern Philadelphia on the Delaware River. For more than 150 years, this 110 acre site was associated with Federal munitions research, development and production. When the U.S. Army decided to excess the facility in 1976, the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) assumed responsibility for the site cleanup to satisfy the requirements of the General Services Administration prior to sale of the property to private developers. A large portion of the old arsenal has been sold to a development consortium and will be developed for use by multiple tenants for light industry. The property closest to the water is intended for use as a regional marina and park to be built by the Pennsylvania State Fish Commission. Projected for completion in 1986, development of this 18-acre facility is expected to cost $3 million.

The redevelopment of a former coal tar refinery site in Renton, Washington is currently in a planning stage. The site has extensive contamination from slag and waste landfilled during the operation of the refinery which produced creosote and pitch for wood preserving. A private development consortium has proposed a remediation scheme which is considered by the Regional EPA officials and local authorities to be sound. The proposed remediation and redevelopment plans have been delayed recently because the site was placed on the National Priorities List (NPL).

CONCLUSIONS

In the past the presence of hazardous substances in soils was not a major public concern. Thus, many contaminated sites were redeveloped with minimal attention to the chemical contaminants remaining in the soil. Old dump sites which received industrial as well as municipal wastes, for example, have often been reclaimed for upgraded uses. Remediation efforts (e.g., excavation of filled materials) were usually undertaken to ensure adequate bearing capacity of the soil rather than to minimize exposure to hazardous materials. Chemical characterization of the soil contamination was usually neglected because it was not deemed necessary.

One type of contaminated site that is encountered frequently is former gas works. At the turn of the century, almost every town had a gas works where coal or oil was converted to gas for lighting and other products. These processes also produced large quantities of solid wastes including heavy tars (containing high concentrations of polycyclic aromatic hydrocarbons) and spent oxides (used in the gas cleanup) which were often disposed on or near the plant site. As natural gas became available, the gas plants became uneconomic and were gradually phased out. Typically the gas plants were located near the center of populated areas (to facilitate distribution) on properties potentially valuable for redevelopment. Thus, many of these sites were redeveloped at a time when soil contamination was not widely recognized as a potential health problem.

In spite of the large number of documented hazardous waste sites in the U.S., relatively few sites have been cleaned up with specific redevelopment in mind. Remedial actions usually are undertaken to contain or remove chemical contaminants with little or no consideration given to the ultimate use of the site. If land reuse is decided prior to the cleanup, there may be opportunity to tailor the cleanup activities to best suit the site redevelopment.

Site redevelopment options are often limited by the extent and nature of the remedial action. Sometimes, however, this can be made an advantage. In one case study, a California condominium development, the site redevelopment plan took advantage of the extensive excavation required for the site cleanup to provide underground parking at the site. This proved to be practical as a design solution and alleviated the problem of filling a large area.

There is a need for policy at the Federal level regarding redevelopment and reuse of uncontrolled hazardous waste sites. Most states do not have the resources to develop the guidelines needed to deal with the cleanup of contaminated land. Almost all states have problems with the "How clean is clean?" issue. Particularly for contaminants that are encountered at many sites, guidance regarding levels that are expected to be safe need to be developed based on realistic exposure scenarios.

The extent of cleanup that is necessary to protect human health and welfare varies with different use categories. Residential development is probably the most sensitive type of land use because of the long term and multiple exposure routes and potential exposure to the most sensitive population segments (e.g., children and elderly persons).

Excavation and removal appears to be the remedial action alternative selected at most sites where there is redevelopment. This is because no one can guarantee that a site is safe (i.e., zero risk) unless all contaminants are removed. Neither a developer nor a municipality can accept responsibility for site safety as long as hazardous materials remain there. In situ treatment approaches are seldom viewed as the best option because they are unproven and because 100 percent detoxification or stabilization cannot be achieved.

If "acceptable levels" are developed to use as criteria for site cleanup decisions, caution must be exercised in applying the criteria at each site. For example, lead levels near major highways are typically high. To require cleanup in urben locations to levels that are considered appropriate for pristine environments would be inappropriate.

Uncontrolled waste site development projects appear to be of two distinctly different types. The first type may be termed the developer-initiated redevelopment effort. Such cases of site cleanup and redevelopment occur in large metropolitan regions and other areas where the locational advantages of a site alone are so great that cleanup costs can be recovered through future resale of the remediated property. In such cases, the decision to remediate and redevelop a specific site is made in the private sector, and the public sector simply regulates and certifies the cleanup process. Such was the case for several of the examples of site redevelopment case studies in California.

The second type of hazardous waste site redevelopment project is the public-initiated project where reuse of the land is clearly secondary in importance to the site remediation that is required for public health and safety. This appears to be the case, for example, with almost all sites on the NPL. For most public-initiated cleanup operations, remediation activities are so complicated and costly that the economic value of the site following cleanup only partially (if at all) justifies the cleanup operation. Where a remediated site passes into public ownership, reuse will probably be determined by the specific property needs of the governing body at that particular location and point in time.

It is important to note that these two types of hazardous waste site redevelopments result from two entirely different motivating forces. In the first case (developer-initiated cleanups), the developer is simply responding to land market forces and diverting into cleanup operations dollars that would otherwise be used to purchase uncontaminated land. In the second case (public-initiated cleanups), the redevelopment decision is made in the public sector, and there is no explicit requirement that cleanup costs be recovered through future uses of the property.

Of the sites in reuse examined in this study, few involved Superfund monies. The complexity of the legal process in dealing with Superfund site cleanup is not conducive to deliberate redevelopment efforts. Even in cases where emergency remedial response actions have been completed, it appears that the site may remain in receivership and go unused for long periods of time (typically several years) while the courts decide cost recovery and/or property ownership issues.

California appears to lead other states in the formulation and enactment of legislation and regulations pertaining to the cleanup and redevelopment of properties contaminated with hazardous waste. With adoption of the California Assessment Manual (CAM) Standards, California has begun to define quantitatively what is meant by "hazardous waste contamination." Their program for guiding redevelopment of contaminated land appears to be the most advanced state program in the Nation.

There are many sites in the U.S. that require remedial actions and reuse planning. The learning experiences of developers and public agencies addressing the issues arising from contaminated land and its redevelopment can benefit others who might be involved in similar activities. Therefore, an ongoing effort to assemble the type of information provided through this study could serve as a valuable source of information for Federal, state, and local authorities. Such information would also be of value to developers in the private sector who, having more knowledge of successful redevelopment projects as well as potential pitfalls, might be more inclined to get involved in remedial actions.

SECTION 3

APPROACH AND GENERAL OBSERVATIONS

APPROACH TO INFORMATION GATHERING

Background information concerning hazardous waste site remediation and reuse was assembled from three principal sources:

- telephone and on-site interviews with Federal, state, and local environmental officials;
- project records and consultants' reports documenting specific site remediation/redevelopment projects; and
- journal articles and published conference proceedings.

To identify sites that might serve as case studies for remediation and reuse, telephone and personal interviews were conducted with Federal and state officials involved with uncontrolled hazardous waste site cleanups. In addition to contacts with environmental officials in all 50 states, information was solicited from each of the ten EPA Regional Offices and each of the ten EPA Regional Superfund Offices. Inquiries were also made to the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), the U.S. Army Corps of Engineers, and the Regional Offices of the U.S. Department of Housing and Urban Development. This approach to information gathering was highly successful and led to the identification of candidate sites for detailed study. Initial telephone interviews were conducted during the period July through December of 1983. Many follow-up contacts were made during 1984 and 1985. Federal and state offices and officials contacted are listed in Appendix A.

A carefully designed literature search of 13 online data bases was also conducted, but proved to be of limited value, since there is rarely any mention of site redevelopment in journal and newspaper articles dealing with hazardous waste sites. Thirteen on-line databases were scanned for combinations of the keywords: site, location, reuse, chemical, hazardous, reclaim, dispose, dump, tip, and expose." The following databases were searched:

- NTIS (National Technical Information Service), consists of government-sponsored research, development, and engineering plus analyses prepared by federal agencies, their contractors or grantees;

-- NEWSEARCH, a daily index of news stories from 1400 newspapers, magazines, and periodicals;

-- NATIONAL NEWSPAPER INDEX, a complete index of The Christian Science Monitor, The New York Times, and The Wall Street Journal;

-- TRADE AND INDUSTRY INDEX, abstracts of business journals relating to trade, industry, and commerce;

-- MAGAZINE INDEX, covers 370 popular magazines;

-- UPI News, covers United Press International news stories;

-- GPO MONTHLY CATALOG, contains records of reports, studies, fact sheets, maps, handbooks, conference proceedings, etc., issued by all federal agencies;

-- CHEMICAL EXPOSURE, abstracts of chemical industry and professional journals;

-- PUBLIC AFFAIRS INFORMATION SERVICE INTERNATIONAL, refers to all fields of social science;

-- MEDLINE, indexes 3000 journals covering biomedical subjects;

-- ENVIROLINE, produced by the Environmental Information Center, covers information related to environmental issues;

-- POLLUTION ABSTRACTS, references environmentally related literature on pollution, its sources, and its control; and

-- LEGAL RESOURCE INDEX, complete indexing of law journals and newspapers.

Most of the articles identified through the literature search reported problems and activities at sites where hazardous waste contamination had come to public attention. Moreover, such sites were typically of interest to the media because of the contamination that was still there. In the U.S., the open literature available describing remediation of hazardous waste sites is almost exclusively contained in U.S. EPA-sponsored research reports and conference proceedings. These documents address reuse only occasionally; most discussions are directed to the manner by which hazardous waste contamination was treated or contained. Thus, to locate examples of hazardous waste site cleanup and redevelopment in the U.S., more direct data gathering methods were relied upon.

Information on candidate case studies was assembled from pertinent project records, local newspaper articles, and various types of government and contractor reports pertaining to specific sites that were identified through telephone contacts. These materials were reviewed carefully to decide if a particular site was appropriate for further study. An effort was then made to assemble complete files on these sites to describe site location, ownership, and special characteristics; land use history and redevelopment objectives; the nature of the contamination; the remediation actions taken or planned; and the specific criteria used to guide the cleanup effort. This detailed information gathering required additional telephone interviews and, in some cases, site visits. Site visits proved to be highly effective in assembling the background documentation for several sites.

GENERAL OBSERVATIONS

From the record searches and interviews, several findings of a general nature emerged. One observation was simply the small number of Superfund-assisted sites that have become available for redevelopment. Many uncontrolled hazardous waste sites do not pose an immediate threat to public health or welfare as long as they are left undisturbed, and thus they do not meet the criteria to qualify them as NPL sites. As a result, cleanup must be initiated by the local government or by the private sector if site remediation is to be accomplished. Where remediation costs are high, remediation/reuse will be untertaken by the private sector only in areas where land values are so high that cleanup costs can be recovered through rents or resale.

Across the U.S., several contaminated DOD sites have been remediated and turned back to the private sector during the past few years. Efforts to restore hazardous DOD or former DOD properties contaminated by hazardous wastes, unexploded ordnance, and unsafe or unsightly debris will expand under the Defense Environmental Restoration Program (DERP) authorized by Public Law 98-212. DERP covers both active installations and formerly used DOD properties. The U.S. Army Corps of Engineers is responsible for implementing the program at properties formerly used by DOD.

A central issue for the planning of any site redevelopment is the criteria to be used in determining the extent of cleanup that is to be required. Acceptable concentration limits to establish the extent of cleanup that is necessary to protect public health and welfare have not been determined for most toxic substances of concern.

Almost all states have problems dealing with the "how-clean-is-clean?" issue. Since different uses may imply a need for different cleanup criteria, this type of judgment must be made on a case-by-case basis. Residential use is generally felt to require the most stringent cleanup. There are liability issues associated with the reuse of sites when residuals of hazardous materials are allowed to remain. No authority can guarantee zero risk for former hazardous waste sites since total removal of potentially hazardous material cannot be assured. (Can one molecule of certain chemicals cause cancer?). This concern was expressed by many states. Many states indicate that no site has been cleaned to their satisfaction. Thus, these states have not yet confronted reuse issues.

Recognized guidelines pertaining to acceptable pollutant levels include air quality standards, occupational exposure guidelines, drinking water standards, and water quality criteria. Although developed for other purposes, these established sets of guidelines are frequently relied upon as criteria for cleanup.

Most states have not established a systematic screening approach to identify potential hazardous waste sites, including sites with potential for reuse. As a result, plans to develop an uncontrolled hazardous waste site for a sensitive reuse could proceed without coming to the attention of the State authorities. Most states do not have a plan or formal mechanism for dealing with redevelopment of contaminated land. The only work that has been done in some states is the cleanup of spills or other emergency response action.

Several states indicated problems in forcing responsible parties to agree on hazardous waste remedial actions. Remediation efforts that are accomplished by the private sector are usually undertaken in preparation for sale of the land. Companies are reluctant to initiate remedial activities where cleanup criteria are not spelled out completely in advance.

In some cases it has been found that upgraded reuse of property occurs only when the expected property value justifies the expense incurred in cleaning it to the degree necessary to permit a specified reuse. Where remediation costs are high, remediation/reuse will be undertaken by the private sector only in areas where land values are so high that cleanup costs may be recovered through rents or resale.

Some states reported sites that have been cleaned up with public funds (either state or Federal) and that now lie idle awaiting settlement of the issues surrounding the hazardous waste. One question to be resolved relates to who is responsible for bearing the cost of the site remediation. Although the current owner is not the waste generator, he stands to benefit from the hazardous waste removal from his property. In such a case, provision should be made to recover public funds concurrent with the site redevelopment since the cleanup action contributed to the site's potential for redevelopment.

U.S. EPA regional officials and most state environmental officials involved with site cleanup actions do not follow-up on what happens at a site after the cleanup is completed. There is no formal tracking of what happens following the remedial phase. Several officials stated that they recognized this to be a shortcoming in their program.

THE CALIFORNIA PROGRAM

The State of California deserves special discussion in this review of U.S. experience with hazardous waste site redevelopment. California appears to be ahead of all other states with respect to policy and legislation guiding the redevelopment of contaminated land. Within the California Department of Health Services (CDHS) a system has evolved during the last 4 years for regulating the cleanup and redevelopment of abandoned industrial sites and waste disposal areas.

California has developed criteria to explicitly define hazardous wastes. The guidelines contained in the Draft California Assessment Manual, referred to as the CAM Standards, have been revised several times and until very recently were not enforcible. The guidelines were adopted, effective October 27, 1984, as formal definitions of "hazardous" and "extremely hazardous" wastes and are now enforceable. (These guidelines are discussed in more detail in Section 4.)

The CAM Standards were not specifically developed to guide the cleanup at uncontrolled hazardous waste sites, but rather to enable a generator to determine if the waste he produces must be managed as a hazardous material. The informal standards have proved to be useful as criteria to establish the extent of remediation necessary to insure that a site is clean enough to be redeveloped for an upgraded use.

Assembly Bill 2370 (AB 2370) is another important feature in the California program for hazardous waste site remediation. This law authorizes CDHS to impose deed restrictions to forbid sensitive uses on any tract of land (and surrounding properties) that poses a significant threat to the public health. This significant threat must be established through a risk assessment procedure that takes into account the nature of the contaminants present, the potential for exposure, and dose-response relationships that are established for the particular toxicants at issue. Sensitive uses include residential development, schools, recreational areas, and other areas where people (particularly children) and/or animals will be in contact with the soil.

Through its Abandoned Sites Program, CDHS has also developed a systematic procedure to identify sites that are potential hazardous waste sites (i.e., contain hazardous materials in quantities that pose a significant human health hazard). This system has been applied only in certain sections of the state, but it has brought to the attention of the department, either directly or indirectly, numerous sites that will require cleanup.

The California sites treated in detail in Section 5 serve to illustrate the approach used by CDHS in guiding hazardous waste site mitigation and redevelopment efforts.

THE NEW JERSEY ECRA

The State of New Jersey has adopted innovative legislation to insure that the cost of cleanup of hazardous materials will be borne by the owner of the establishment or property that is remediated. ECRA is the acronym for the Environmental Cleanup Responsibility Act, N.J.S.A. 13:1K-6 et seq. (P.L. 1983, c. 330), a New Jersey law which became effective on December 31, 1983. This innovative law imposes pre-conditions on the sale or closure of industrial establishments involved in the generation, manufacture, refining, transportation, treatment, storage, handling, or disposal of hazardous substances or hazardous wastes. Under ECRA, the owner or operator of a firm, or the land on which it is situated, is required to notify the New Jersey Department of Environmental Protection (DEP) within five days of signing a sales contract, execution of an agreement of sale, a decision to exercise an option to purchase, or making public the decision to close the business. In the case of the transfer of property, the owner must, at least 60 days prior to the actual transfer of property, file with the DEP either a negative declaration or a cleanup plan. When closing operations, the owner must notify the DEP either at closing or 60 days following public release of the decision to close by applying for approval of a negative declaration or by submitting a cleanup plan for approval.

SECTION 4

CRITERIA TO GUIDE CLEANUP

As part of each hazardous waste remedial action, an assessment must be made of the contamination at the site. The options for remedial action to remove or otherwise deal with hazardous materials will depend on the nature of the contamination and other site-specific factors and on the level of contamination that will be allowed to remain on-site following cleanup. Thus, a need arises in planning site remediation for criteria to define acceptable levels of pollutants.

A recent report by the U.S. General Accounting Office (GAO) (4) focusing on EPA's efforts to clean up selected hazardous waste sites notes that "Superfund provides that long-term remedies be cost-effective, but no standards exist that specify to what extent sites must be cleaned up to effect permanent remedy". One concern that surfaced during the GAO review was the "lack of environmental standards ... for use in making cost-effectiveness determinations".

This section describes some of the recognized guidelines and methodologies that relate to the "how-clean-is-clean?" issue. Some of the criteria that are discussed were, in fact, developed for different but related purposes. They are discussed here, however, since they can be extended to provide guidance for hazardous waste site cleanup.

In order to determine acceptable contaminant levels in soils, two primary exposure routes are usually considered--

1. inhalation of gases, vapors, or airborne particulate emanating from the site; and
2. ingestion of contaminated drinking water.

Other routes that can contribute to exposure include absorption of pollutants through direct skin contact or uptake of water or soil contaminants by plants and subsequent ingestion by man.

Available guidelines that address air or water quality which might be affected by contamination from a site are described in Sections that follow. Occupational exposure guidelines are also discussed since these values are frequently used to judge the toxic properties of pollutants and to indicate levels of chemical pollutants in air that may be considered to be tolerable. Listings of the various air and water guidelines are given in Appendix B.

The available guidelines pertaining to soil and solid waste are discussed following the guidelines for air and water. Included are the maximum criteria to trigger designation as a RCRA hazardous waste, the Centers for Disease Control recommendation for dioxin in soil, guidelines for sludge application to agricultural soils, natural soil background levels, the California guidelines to distinguish hazardous wastes, and a brief description of four systematic approaches that have been developed to predict acceptable levels of contaminants in soil.

Because of the widespread concern over pollutants with the potential to cause cancer, special consideration is often given during site cleanup to the presence of certain classes of chemicals (e.g., polycyclic aromatic hydrocarbons, chlorinated organics). Although quantitative risk assessments have been performed for only a few materials, a substantial number of pollutants are recognized by one or more authorities as carcinogens. A brief overview of agencies that designate and assess the significance of carcinogens is provided.

GUIDELINES FOR AIR

Existing guidelines for air can be used as criteria to compare against levels of contaminants in ambient air at or near a site and to assess the significance of exposures.

Ambient Air Quality Standards

National Ambient Air Quality Standards have been promulgated (40 CFR, Part 50) for six criteria pollutants--sulfur dioxide, nitrogen dioxide, particulate matter, carbon monoxide, ozone, and lead. The standards are presented in Appendix B, Table B-1. Guidelines for acceptable concentrations in ambient air have not been established, however, for most of the chemicals of concern in hazardous waste.

Occupational Exposure Guidelines

Occupational exposure regulations by the Occupational Safety and Health Administration (OSHA) and recommendations by the National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) are useful for comparing chemical hazards. The occupational exposure guidelines take into account the available data from experimental human and animal studies as well as experience in the workplace. Odor thresholds as well as toxic effects levels from airborne contaminants are important parameters in determining the recommended levels.

The ACGIH Threshold Limit Values (TLVs®) pertain to more than 600 chemical substances and are updated annually (5). Documentation for each recommendation is available from the ACGIH (6). The basis for the NIOSH recommendations are provided in NIOSH Criteria Documents.

The quantitative occupational exposure regulations and guidelines are summarized in Appendix B, Tables B-2, B-3, B-4, and B-5.

GUIDELINES FOR WATER

The potential for hazardous contaminants in soils to migrate to groundwater or to surface water is often of major concern. Detailed evaluation of cleanup levels frequently involves modeling the movement of contaminants to groundwater or surface water and estimating the maximum levels in soil that will not interfere with acceptable water quality characteristics. Drinking water standards and water quality criteria developed by the U.S. EPA are widely used as guidance for acceptable levels in water. Water quality standards or criteria developed by individual states may also be applied.

National Drinking Water Regulations

National Interim Primary Drinking Water Regulations (40 CFR, Part 141) and Secondary Drinking Water Standards (40 CFR, Part 143) are authorized under the Safe Drinking Water Act. The Primary Regulations specify maximum levels for several inorganic contaminants, selected chlorinated organics, microbial contamination, radionuclides, and turbidity. The purpose of the Primary Regulations is to protect public health. Secondary Standards deal with the taste, odor, color, and corrosivity of drinking water. The Primary Drinking Water Regulations and Secondary Drinking Water Standards are listed in Appendix B. (See Tables B-6, B-7, B-8, and B-9.)

Office of Drinking Water Health Advisories

Informal guidelines for concentrations of certain organic chemicals in drinking water have been developed by the Health Effects Branch, Criteria and Standards Division, U.S. EPA Office of Drinking Water. The informal, unpromulgated Health Advisories (formerly called "Suggested No Adverse Response Levels" [SNARLs]) have been developed for more than 20 organic chemicals. On April 30, 1982, "Inside EPA" published the "SNARLs" for 16 chemicals. Others have been released for public information because they were used in litigation actions. Although many of the Health Advisories are in draft form and labeled "do not cite or quote", they have received wide distribution in the health effects community. The Advisories have undergone both internal and external peer review and are relied upon as guidance in many emergency situations involving quality of drinking water. A summary of the Advisories is provided in Appendix B, Table B-10.

The Health Advisories pertain to levels acceptable for 1-day, 10-day or "longer-term" exposure. It should be emphasized that "longer-term" in this case refers to 1 or 2 years, but not to lifetime exposure. The Advisories have been developed as the need arose in connection with spills or accidents. The needs were brought to the attention of the Drinking Water Office by EPA Regional Offices or state environmental agencies.

As yet, the program to develop the Health Advisories has not been formalized although this may change in the near future. Currently, substantial emphasis is being placed on the Advisories, and there will be an effort in the future to update those previously developed and to issue new ones. Pollutants to be addressed in upcoming advisories will be selected to respond to recommendations made by the EPA Regional Offices and others who rely on the Advisories for guidance in emergency situations.

Water Quality Criteria

Specific quantitative water quality criteria for protection of human health have been established for many chemicals of broad concern. Three independent sets of Water Quality Criteria that are widely recognized are the U.S. EPA 1980 Criteria (7), the U.S. EPA 1976 Criteria (8), and the National Academy of Sciences/National Academy of Engineering (NAS/NAE) 1972 Criteria (9). Each recommended water criterion based on potential health effects is supported by considerable documentation. In spite of this, there is not always agreement among the three sets of criteria. None of the criteria carry regulatory status.

The U.S. EPA 1980 Criteria address 129 pollutants including several potentially carcinogenic substances. Estimated concentrations of potential carcinogens corresponding to a specified risk level are given. The levels are based on risk assessments performed by the U.S. EPA's Carcinogen Assessment Group (CAG). Generally, an incremental increase in risk of cancer over 70 years of 1/1,000,000 is judged to be an acceptable risk.

Water Quality Criteria for protection of aquatic life have been developed by NAS/NAE and by the U.S. EPA. Criteria were also made available in 1980--a summary of the water quality criteria for 64 toxic pollutant categories was published in the *Federal Register*, November 28, 1980. The availability of 64 water quality criteria documents was also announced in this *Federal Register* notice.

The 1980 criteria for protection of aquatic life specify both maximum and 24-hour average levels. The maximum value, derived from acute toxicity data, establishes a ceiling value for excursions (i.e., brief intervals of higher concentration exposure) over the average 24-hour level which will not cause harm. For most substances, separate criteria are derived for freshwater and saltwater. For those pollutants where data are insufficient to allow the derivation of a criterion, narrative descriptions are presented of apparent threshold levels for acute and/or chronic effects. These descriptions are intended to convey a sense of the degree of toxicity of the pollutant.

In 1984 EPA published a new set of guidelines for deriving water quality criteria for protecting aquatic life. These new guidelines establish criteria for nine inorganic chemicals. Criteria now set a maximum concentration and a 30-day average concentration rather than the 24-hour average used earlier. Excursion over the average is limited to one 96-hour episode in any 30 days. If adequate information is available, separate criteria are derived for freshwater and saltwater. The LC50 (lethal concentration for 50 percent of the test animals), which had been used, is no longer the preferred toxicity test. Rather, an effective concentration (EC50) where organisms that become immobilized are included with those killed is the parameter for determining criteria. Additional changes to earlier guidelines include (1) the preferred duration of acute tests is 96 hours, (2) test results from aquatic plants are more stringently applied, and (3) a more diverse set of species is required to develop a criterion.

Water quality criteria are presented in Appendix B, Tables B-11, B-12, and B-13. Criteria from 1984, 1980, and 1976 are included.

GUIDELINES FOR SOIL AND SOLID WASTE

Recognized guidelines describing levels of chemical contaminants that are significant in soils or solid wastes have been established for only a few substances, and the existing guidelines pertain only to very specific situations.

RCRA Guidelines

The U.S. EPA has determined that solid waste that exhibits a toxicity characteristic will be designated a hazardous waste and subject to the provisions of RCRA. In developing the characteristic, EPA considered a waste mismanagement scenario involving the co-disposal of toxic wastes in an actively decomposing landfill which overlies an aquifer that supplies drinking water. The toxicity characteristic is based on an extraction procedure (EP) and termed "EP toxicity" (40 CFR, Part 261.24).

A waste is found to be hazardous due to the EP toxicity characteristic if any toxic contaminant concentration in the extract (1:20) exceeds 100 times the National Interim Primary Drinking Water Standard. The EP toxicity characteristic serves as a test for identifying wastes which are capable of posing a substantial present or potential hazard when improperly managed. The maximum concentrations of contaminants in the 1:20 waste extract that trigger the hazardous determination based on EP toxicity are listed in Appendix B, Table B-14.

California Guidelines

The California Hazardous Waste Control Act requires the State Department of Health Services (CDHS) to develop and adopt by regulation criteria and guidelines for the identification of hazardous wastes and extremely hazardous wastes. Draft criteria and guidelines have been developed and are presented in the California Assessment Manual for Hazardous Wastes (CAM). The earliest version of the CAM was developed in 1978. Several subsequent versions have been prepared, and feedback on the criteria and

CAM standards have been elicited from many organizations since 1978. During this period, the criteria have been used in California as informal guidelines to define hazardous wastes.

The CAM Standards are used as guidelines by the CDHS to determine what material must be removed from a hazardous waste site in order that the Department no longer considers the subject property as potential "hazardous waste property." It should be emphasized that the CAM Standards are used as guidelines and not as rigid standards. In some sites for example, the background level for a given contaminant may exceed the CAM standard. This would be the case for lead at a site near a major highway. In such circumstances, the background level is considered in specifying tolerable levels of contaminants at a site. A rule of thumb sometimes used is that a tolerable level is twice the background concentration.

The current CAM standards are incorporated in the proposed changes in the California regulations regarding criteria for identification of hazardous and extremely hazardous wastes. The proposed regulations have been published and defended in a "Statement of Reasons" in 1983 (10). Following public hearings on the proposed regulations (December 20, 1983), the CAM standards were accepted and filed with the Secretary of State on September 17, 1984. The standards became effective 30 days after they were filed.

The proposed hazardous waste identification regulations define the characteristics of toxicity, ignitability, corrosivity, and reactivity and set forth tests for these characteristics. In addition, concentration limits are proposed for selected persistent and bioaccumulative toxic substances which commonly occur in hazardous wastes. The Department has attempted to establish quantititative limits against which a waste can be compared to determine if it is a hazardous waste. The proposed regulations recognize that potential hazard is dependent upon concentrations of hazardous substances in the waste.

CAM Criteria for Identification of Toxic Hazardous Wastes--

A waste or a material is defined as hazardous because of its toxicity if it meets any of the following conditions:

-- Acute oral LD50 of less than 5,000 mg/kg.

-- Acute dermal LD50 of less than 4,300 mg/kg.

-- Acute 8-hour inhalation LC50 of less than 10,000 ppm.

-- Acute aquatic 96-hour LC50 of less than 500 mg/L measured in soft water with specified conditions and species.

-- Contains 0.001 percent by weight (10 ppm) of any of 16 specified carcinogenic organic chemicals. (See listing below, under Carcinogenic Substances)

- Poses a hazard to human health or the environment because of its carcinogenicity, acute toxicity, chronic toxicity, bioaccumulative properties, or persistence in the environment.

- Contains a solubilized or extractable persistent or bioaccumulative toxic substance at a concentration exceeding the established soluble threshold limit concentration (STLC). (See Table 2.)

- Contains a persistent or bioaccumulative toxic substance at a total concentration exceeding its total threshold limit concentration (TTLC). (See Table 2.)

- Is a listed hazardous waste (California list consistent with the Federal RCRA list), designated as toxic.

- Contains one or more materials with an 8-hour LC50 or LCLo of less than 10,000 ppm, and the LC50 or LCLo is exceeded in the head space vapor. (Test method is specified.)

Extensive documentation has been prepared as background for the recommended STLC and TTLC values listed in Table 2.

CAM Criteria for Identification of Extremely Hazardous Wastes--
The California code defines "extremely hazardous waste" to mean

> "...any hazardous waste or mixture of hazardous wastes which, if human exposure should occur, may result in death, disabling personal injury or illness because of the quantity, concentration or chemical characteristics of the hazardous waste or mixture of hazardous wastes."

Examples of materials that are extremely hazardous because of their high acute toxicity are cyanides, hydrogen sulfide, and parathion.

A waste or a material is designated as extremely hazardous if it meets any of the following criteria--

- Acute oral LD50 of less than or equal to 50 mg/kg.

- Acute dermal LD50 of less than or equal to 50 mg/kg.

- Acute inhalation LC50 of less than or equal to 100 ppm.

- Contains 0.1 percent by weight of any of 16 specified carcinogenic organics. (See Section on Carcinogenic Substances.)

TABLE 2. CALIFORNIA GUIDELINES FOR SOLUBLE THRESHOLD LIMIT CONCENTRATION (STLC) AND TOTAL THRESHOLD LIMIT CONCENTRATION (TTLC) VALUES FOR PERSISTENT AND BIOACCUMULATIVE SUBSTANCES (mg/kg wet weight)

Substance[a]	STLC[b]	TTLC[b]	TTLC[c]
Aldrin	0.14	1.4	140
Antimony	100	500	-
Arsenic	5.0	500	50,000
Asbestos	-	1.0(%)	-
Barium (excluding barite)	100	10,000[d]	-
Beryllium	0.75	75	7,500
Cadmium	1.0	100	10,000
Chlordane	0.25	2.5	250
Chromium (VI)	5	500	-
Chromium (III)	560	2,500	-
Cobalt	80	8,000	-
Copper	25	2,500	-
DDT, DDE, DDD	0.1	1.0	-
2,4-Dichlorophenoxyacetic acid	10	100	10,000
Dieldrin	0.8	8.0	800
Dioxin (2,3,7,8-TCDD)	0.001	0.01	1.0
Endrin	0.02	0.2	20
Fluoride salts	180	18,000	-
Heptachlor	0.47	4.7	470
Kepone	2.1	21	2,100
Lead (inorganic)	5.0	1,000	-
Lead (organic)	-	13	1,300[e]
Lindane	0.4	4.0	400
Mercury	0.2	20	2,000
Methoxychlor	10	100	-
Mirex	2.1	21	2,100
Molybdenum	350	3,500	-
Nickel	20	2,000	-
Pentachlorophenol	1.7	17	1,700
Polychlorinated biphenyls (PCBs)	5.0	50	5,000
Selenium	1.0	100	10,000
Silver	5.0	500	-
Thallium	7.0	700	70,000
Toxaphene	0.5	5.0	500
Trichlorethylene	204	2,040	-
2,4,5-Trichlorophenoxy propionic acid	1.0	10	1,000
Vanadium	24	2,400	-
Zinc	250	5,000	-

[a] Values for inorganics apply to the element and its compounds and are based on the concentration of the element whether free or combined.

[b] Criteria are for designation as hazardous.

[c] Criteria are for designation as extremely hazardous.

[d] Excluding barium sulfate.

[e] Dry weight basis, as lead.

-- Has been shown through experience or testing to pose an extreme hazard to the public health because of its carcinogenicity, bioaccumulative properties, or persistence in the environment.

-- Contains a persistent or bioaccumulative toxic substance at a total concentration exceeding its TTLC as specified for extremely hazardous wastes (see Table 2).

-- Is water-reactive (i.e., has the capability to react violently in the presence of water and to disperse toxic, corrosive, or ignitable material into the surroundings).

Carcinogenic Substances--

The carcinogenic substances specified in the California criteria for hazardous and extremely hazardous materials have been designated potential carcinogens by the Occupational Safety and Health Administration (OSHA). Under the California criteria, these substances cause a material to be designated as hazardous if they are present at a concentration of 0.001 percent by weight (10 ppm). A material containing 0.1 percent of these substances is designated extremely hazardous. The chemicals are the following:

2-Acetylaminofluorene
Acrylonitrile
4-Aminodiphenyl
Benzidine and its salts
bis(Chloromethyl) ether (BCME)
Chloromethyl methyl ether (CMME)
1,2-Dibromo-3-chloropropane (DBCP)
3,3'-Dichlorobenzidine and its salts (DCB)
4-Dimethylaminoazobenzene (DAB)
Ethyleneimine (EL)
alpha-Naphthylamine (1-NA)
beta-Naphthylamine (2-NA)
4-Nitrobiphenyl (4-NBP)
N-Nitrosodimethylamine (DMN)
beta-Propiolactone (BPL)
Vinyl chloride (VCM)

Other Criteria to Define Hazardous Wastes--

California criteria for defining hazardous wastes that are ignitable and reactive are identical to the Federal criteria for hazardous wastes under RCRA defined at 40 CFR, Part 261. The California corrosivity criteria differ from the Federal criteria only in the addition of a pH test for nonaqueous wastes.

Centers for Disease Control Recommendation

The Centers for Disease Control (CDC) in Atlanta, Georgia, provides assistance to states and regional offices regarding environmental impacts of chemical toxicants. CDC often reviews and critiques environmental assessments prepared by other agencies. Although the CDC has avoided recommending acceptable contaminant levels for most pollutants studied, an action level for dioxin has been endorsed.

Dioxin-contaminated sites that pose a human health threat have been the subject of recent analyses by the CDC. It has been determined that 1 ppb of dioxin is detrimental to public health and that people should be dissociated from the hazard. A level of 1 ppb of dioxin (2,3,7,8-TCDD) in soil is recommended as an action level. In cases where soil concentrations exceed 1 ppb, it is recommended that potential human exposure to the contamination be examined further. If there is human exposure to 1 ppb or higher on a regular basis, cleanup is indicated.

Guidelines for Sludge Application

Land treatment is one method used to manage wastes, particularly sludges, as an alternative to land disposal. In land treatment, a layer of sludge is spread over an area and mixed with the top layer of soil. The sludge is then decomposed by chemical and biological processes rendering it nontoxic and suitable for growing crops. There is, however, some concern as to the level of certain pollutants (e.g., heavy metals) that can be applied to the soil without causing a problem from plant uptake. Plant uptake of an element from soil is a function of availability of the element in the soil, movement of the element to the root, absorption by the root, and translocation of the element in the plant. Soil characteristics such as pH, particle size, colloidal properties, salinity, moisture, and compaction may profoundly affect the bioavailability of contaminants to plants and microorganisms as well as determining the rates of degradation and transport of pollutants in the soil.

Using soil cation exchange capacity (CEC) as a method of grading soils on the basis of their affinity for metals, the U.S Department of Agriculture together with the Land Grant Universities have proposed interim limits on metal application to agricultural soils (11). The recommendations developed to guide the rate of sludge application on farmland are listed in Appendix B. These limits are generally considered to be conservative.

Background Levels

One measure of the significance of contaminants in soil or solid waste samples may be determined by comparing the levels with reported naturally occurring concentrations. Provided that levels are within the range that may occur naturally, one might conclude that the sample contaminant levels are of little consequence. A summary of levels of trace and minor elements in soils is provided in Appendix B.

Methods for Developing Guidelines

Although a formal systematic approach to determine acceptable levels of contaminants in soils has not been formally adopted at the Federal level, several candidate methods to determine acceptable levels have been described in the literature. Examples of these are the Multimedia Environmental Goals (MEGs), the Composite Hazard Index; the Preliminary Pollutant Limit Values (PPLVs); and the Monitoring Trigger Levels (MTLs). These approaches are described briefly below.

MEGs Methodology--

The methodology set forth in the initial MEGs report (12) was a first attempt to provide a systematic approach to establish a set of trigger levels for use in environmental assessment. The methodology establishes a hierarchy to combine a number of models (including ones developed expressly for the MEGs and ones developed by others) to determine numerical goals for almost any chemical toxicant. Separate values for air, water, and soil based on health and ecological effects are computed. There is general agreement that the MEGs values derived in accordance with the original methodology provide a reasonable basis for relative ranking of chemical toxicants. The MEGs should not be interpreted as absolute thresholds, however, as they are generally overly conservative. The MEGs work comprises background information summaries and the calculated MEGs values for more than 600 chemical species (13).

Composite Hazard Index--

A paper published in 1978 (14) describes a hazard assessment methodology for limiting human exposures to environmental pollutants such that exposure or dose will not exceed some preselected value. The method, called the Composite Hazard Index, takes into account an estimation of total pollutant intake and the resulting health effects based on contributions from all possible exposure routes. The methodology is based on consideration of the interrelationships between environmental compartments. The Hazard Index is the ratio of some measure of exposure to the corresponding limit that should not be exceeded because of health risks to human beings.

The Composite Hazard Index assessment methodology has been applied to cadmium releases from a smelter complex. The limiting cadmium air concentration is calculated as the air concentration that would limit the accumulation of cadmium within the human kidney cortex to below the 200 microgram per gram level over a 50-year exposure period.

Preliminary Pollutant Limit Values--

Preliminary Pollutant Limit Values for human health effects were originated at the U.S. Army Medical Bioengineering Research and Development

Laboratory to provide a rational approach to guidelines for removal of substances from heavily contaminated soil. The approach is described in a paper in 1980 (15) and developed in more detail in a later report (16). The approach involves a systematic analysis of every potential exposure route in order to identify the most sensitive exposure pathway and the maximum acceptable level of contamination that can be safely tolerated. The PPLV approach has been applied at several military sites in an attempt to determine how much cleanup is necessary to make the land safe for reuse (17); (18); (19).

Monitoring Trigger Levels--

The development of Monitoring Trigger Levels (MTLs) is an outgrowth of the earlier MEGs work. MTLs are intended to guide decisions concerning which contaminants are to be monitored and the necessary sensitivity of the sampling and analysis program. The monitoring may be associated with a new industrial facility, uncontrolled site remediation, or other activities. One of the models incorporated in the MTLs approach that is particularly applicable to site cleanup involves direct ingestion of soils by children.

It is recognized that adults often ingest soils and dusts through eating food with unwashed hands and through eating food which has not been adequately washed or which has been prepared on contaminated surfaces. The rate of soil ingestion for adults, however, is much lower than that projected for a young child in the "oral stage." Older children also may ingest larger amounts of soil than do adults since they will often eat food that has been dropped or placed on the ground or on dust-coated surfaces.

The MTLs report (20) was peer reviewed in early 1984. The report may be obtained through the EPA Project Officer.

NONTHRESHOLD POLLUTANTS

Chemical pollutants that are classified as potential carcinogens are often termed "nonthreshold" pollutants. The concept of nonthreshold means that exposure at any concentration above zero has an associated carcinogenic risk. A substantial number of pollutants have been designated as potential carcinogens and are therefore of particular concern in site cleanup actions.

Recognized authorities that have published lists of carcinogenic substances include the following:

-- International Agency for Research on Cancer (IARC)

> Based on evaluations of more than 500 chemical substances or processes, the IARC has labeled 42 substances as having "a positive association or a strong suspicion of an association with human cancer" (21). Conclusions of the IARC reflect the extent and nature of the available data in humans and in animals. Sufficient evidence of carcinogenicity in animals is noted for more than 140 chemicals.

- U.S. Department of Health and Human Services (DHHS)

  A list of 117 agents was published in 1983 in the Third Annual Report on Carcinogens by the National Toxicology Program (NTP). The list reflects evaluations of the IARC and findings of the National Cancer Institute (22).

- U.S. EPA Carcinogen Assessment Group (CAG)

  A list of 150 chemical substances has been compiled by the CAG. CAG has determined that there is strong evidence that these chemicals can, under certain circumstances, cause cancer in humans or can cause cancer in animals (23). The list includes, but is not limited to, those chemicals for which risk assessments have been performed. There is considerable overlap (though not complete agreement) between the CAG conclusions and IARC evaluations.

- American Conference of Governmental Industrial Hygienists (ACGIH)

  Fifteen substances are designated Human Carcinogens, and 38 industrial substances are listed as "Suspect of Carcinogenic Potential for Man" (5).

- Occupational Safety and Health Administration (OSHA)

  OSHA regulations address 21 substances that are identified as potential carcinogens.

- National Cancer Institute (NCI)

  NCI has compiled a list of 41 "chemicals and mixtures that have been found to cause cancer in man by direct observation of exposed populations." In addition, seven manufacturing exposures are designated on the basis of "evidence of carcinogenic effects in exposed people."

A listing of some of the environmental pollutants that are recognized by these agencies as potential carcinogens is given in Appendix B.

SECTION 5

RECLAMATION AND REDEVELOPMENT CASE STUDIES

Although redevelopment is not currently planned for the majority of the uncontrolled hazardous waste sites most publicized in the media, there are numerous cases in the U.S. where redevelopment at formerly contaminated sites has been successful. This Section describes the experience at 16 sites where redevelopment has followed (or is planned to follow) the cleanup of uncontrolled hazardous waste. Six of the sites are located in California. Others are in Florida, Maryland, Nebraska, New Jersey, New York, Pennsylvania, Vermont, and Washington.

HERCULES PROPERTIES, HERCULES, CALIFORNIA (Three Reclamation/Redevelopment Case Studies)

Site Location and Special Characteristics

This site is located in the City of Hercules, California on the east side of San Pablo Bay in Contra Costa County approximately ten miles north of Berkeley. The San Pablo Bay is visible from numerous locations along this hilly site of approximately 202 hectares (500 acres). This scenery, together with the site's advantageous location within the San Francisco-Oakland metropolitan area, contribute to the high economic value of the site.

Land Use History and Redevelopment Objectives

Historically, the City of Hercules had always been a small (one square mile) "company town" associated with the Hercules Powder Company which manufactured dynamite and other munitions at that location from 1912 until 1963. Under contract to the U.S. government, Hercules Powder manufactured trinitrotoluene (TNT) on the northern part of the site from 1918 to 1928. After 1928, this northern part of the site was unused and served principally as a buffer zone between the company's dynamite factory at the center of the site and the adjacent town of Rodeo to the north.

In 1963, Hercules Powder converted its dynamite plant into a facility for the production of fertilizer. Operations at the Hercules Powder fertilizer plant included units for producing ammonia, methyl alcohol, formaldehyde, urea, nitric acid, ammonium nitrate, and nitrogen tetroxide (an oxidizer used in liquid propellants). In 1970-71 a series of ponds were constructed for on-site treatment of wastewater. In 1976, Hercules Powder sold its fertilizer plant and surrounding property to Valley Nitrogen Producers, Inc. who continued to produce ammonia, methyl alcohol, urea, nitric acid, and solid and liquid ammonium nitrate. Valley Nitrogen closed down its operations in 1977.

In 1979 the entire Hercules tract was purchased by Hercules Properties, Ltd., a development corporation. Since then, Hercules Properties has sold various parcels of the original tract to other developers. The California Department of Health Services (CDHS) has been involved with remediation/reuse activities at this site since 1980 when the City of Hercules approached CDHS with its area-wide development proposal and requested aid in resolving the hazardous waste issues associated with the former Hercules properties. Formal mitigation plans based on the nature of the contamination and the intended reuse have been developed and approved by the CDHS for five parcels (24). To date, approximately 131 hectares (325 acres) have been cleaned up and redeveloped. Still not characterized or mitigated, however, is the central area of the original Hercules Powder property containing the old factory structures and storage tanks associated with the manufacture of dynamite and fertilizer.

Three of the site redevelopment efforts at Hercules are described below. The information presented on these sites has been assembled from the files of CDHS and from interviews with CDHS staff involved in the site cleanups. The three redevelopment efforts are:

Citation Builders--
The southernmost 40.5 hectares (100 acres) of the original tract were sold to Citation Builders in 1980. Citation completed cleanup of their site in 1981 and developed Bayside Village, a single-family subdivision complete with public school.

Bio-Rad Laboratories--
The northernmost 70.8 hectares (175 acres) of the original tract were sold to Bio-Rad Laboratories who completed their cleanup operations in 1983. Bio-Rad is currently developing an industrial park on their portion of the tract.

D&S Company--
A tract of 20 hectares (50 acres) midway between the Bio-Rad and Citation tracts was purchased by D&S Company, another development corporation. D&S completed cleanup of their site in 1983 and have now constructed condominiums known as Hercules Village.

Nature and Extent of Contamination

Each of the three developers (Citation Builders, D&S Company, and Bio-Rad) retained the same consulting firm--Western Ecological Services Company (WESCO)--for site characterization and remediation engineering. Separate site characterization studies performed by WESCO for these three developers indicated the environmental hazards described below. Groundwater contamination was not a problem at any of the sites. Also it was recognized that the underlying groundwater was of limited usefulness because of high salinity (24).

Citation Builders--

Analysis of soil samples taken from the Citation tract indicated the presence of lead in excess of background levels. The highest levels of lead were found in an area proposed for a public school. Here lead concentrations were as high as 180 ppm in surface samples and 530 ppm in samples several feet below the surface. No other metals were found in any significant concentrations on the Citation tract.

D&S Company--

Located on the D&S tract were four abandoned wastewater ponds that had been used previously for on-site treatment of contaminated water. One of these ponds was constructed of concrete. Around three of these ponds analyses indicated elevated levels of arsenic (120 ppm), lead (3,600 ppm), dinitrotoluene (DNT) and dinitrobenzene (DNB) (3,700 ppm), chromium (390 ppm), zinc (4,860 ppm), and other metals.

In addition to the soil contamination associated with the ponds, several areas of denuded vegetation were also found to be contaminated with lead. Still another circular depression on the site was found to contain elevated levels of arsenic.

Red-stained water taken from an excavated area of the site was found to contain the explosives DNT and DNB. This water was further tested in bioassays to determine potential effects on aquatic life. Even after dilution ten-fold, 100 percent mortality in a test population of fathead minnows occurred within 24 hours.

Bio-Rad Laboratories--

Since this part of the site had been used for TNT production, extensive characterization of the Bio-Rad site was undertaken using a three-phase sampling and analysis plan. This plan was designed to sample the property systematically for toxic waste contamination. Of greatest concern were areas that might be contaminated by heavy metals and explosives. (Explosives though present at less than the level of concern due to explosion hazards are toxic and persistent.) Surface water and groundwater samples were also analyzed. The site investigation resulted in the identification of 18 problem areas.

With only a few exceptions, the 18 problem areas on the property were contaminated with one or more explosives (DNT, TNT, DNB) or one or more heavy metals (lead, zinc, copper, or cadmium). Heavy metal contamination usually occurred in association with deteriorating, leaking drums that were found on the site. Contamination by explosives was generally associated with denuded patches of red-stained soils. (The red stain results from the optical isomerization of TNT usually referred to as the Openheimer complex.) With two exceptions, significant heavy metal contamination was restricted to the top few inches of surface soil. Explosives also were found, primarily in the top several centimeters of surface soils. Leaching tests confirmed that there was very little tendency for these contaminants to migrate downward into the soil.

Site Remediation

Again the same engineering consulting firm, WESCO, assisted all three developers in the planning and execution of all site remediation activities. Because all site remediation had to eventually receive the approval of CDHS, in numerous instances, WESCO was also involved in negotiating "acceptable" remediation activities with CDHS on behalf of its developer clients. Specific remediation activities at the three sites are described below.

Citation Builders--

The one-half acre intended for the school (that had shown lead concentrations of 180 to 530 ppm) was scraped, limed, and covered with six feet of fresh fill. In this area 7-20 cm (3-8 inches) of lead-contaminated soil was removed to a Class II-1 landfill in Stockton, California. Lime (4.48 metric tons per hectare or two tons per acre) was worked into the subsoil to effectively neutralize and immobilize any lead remaining. Following these operations, field tests verified that the limed soils were in the pH range of 6.6 to 8.0.

D&S Company--

All previously detected contaminants, as well as additional contaminants discovered during the course of the exacavation, were removed to a Class II-1 landfill. Where contamination was heaviest, all soil down to bedrock was removed. In total, almost 7,633 cubic meters (10,000 cubic yards) of contaminated soil were removed from the site.

Some minor residues containing DNT and DNB at the bottom of a pit were left on-site and covered by 3.05-3.66 meters (10-12 feet) of clean fill material. This pit was located on a parcel of land which was not planned to be developed for residences. A two-year well-monitoring program was required by the California Regional Water Quality Control Board to detect any deterioration of underlying groundwater.

Bio-Rad Laboratories--

Remediation of the Bio-Rad site consisted primarily of removing the deteriorating metal drums found on the site and excavating and removing the contaminated soils found in the vicinity of these drums. A total of 1,833 cubic meters (2,402 cubic yards) of contaminated soil and other materials was removed to IT's Class I disposal site in Benicia, California. Post-cleanup soil samples were provided to CDHS to verify completion of the mitigation effort (i.e., that levels of contaminants were below the threshold criteria established by CDHS).

Criteria for Cleanup

In 1981 when Citation Builders completed remediation of their site, hazardous waste site cleanup criteria were not yet fully developed by CDHS. Because of the sensitive use intended for the site (i.e., school and residential use) Citation Builders was required to remove all soil with lead concentrations of 50 ppm or greater.

When the D&S Company and Bio-Rad Laboratories undertook their cleanup activities, the cleanup criteria listed in Table 3 were applicable. The cleanup criteria for land to be developed for industrial use are considerably less stringent (typically, by a factor of ten) than the criteria listed for land to be developed for residential or other use associated with children or other vulnerable biological receptors.

It should be noted that the criteria recognized by CDHS for the Citation, D&S, and Bio-Rad Laboratories sites were more stringent than the California Assessment Manual (CAM) standards adopted in 1984 (see discussion of the CAM standards in Section 4).

HOMART DEVELOPMENT, SOUTH SAN FRANCISCO, CALIFORNIA

Site Locations and Special Characteristics

The 47-hectare (117-acre) Homart Development Company (Homart) site is located in the City of South San Francisco just east of the Bay Shore Freeway. When redevelopment of the site was begun, 8.5 hectares (21 acres) were covered by buildings and pavements which required demolition and removal. Some 39 hectares (96 acres) were exposed ground surface.

Ground surface elevations range from 3.35 meters (11 feet) above mean sea level along the southern boundary to 23.16 meters (76 feet along) the eastern property line. The Colma formation underlying the site is extremely tight, has a high heavy metal attenuation capability, and a very low permeability rate.

Land Use History and Redevelopment Objectives

The Homart site was formerly the site of a steel mill and fabrication plant operated by Bethlehem Steel. The plant, operated from 1903 to 1977, used coal-fired open hearth furnaces. During the 1960's the only operation at the plant was a steel galvanizing operation. A wire and netting manufacturing facility, Edwards Wire Rope, also occupied one portion of the site. Steel wire was drawn and galvanized at this plant.

Over a period of 75 years, metallic slag, soil and debris containing heavy metals and other processing wastes, including oils and acids, were deposited on the land or used as fill material at various locations on the site. In addition, specific manufacturing, operating and storage activities

TABLE 3. CALIFORNIA DEPARTMENT OF HEALTH SERVICES RECOMMENDED TOXIC WASTE REMOVAL CRITERIA APPLIED TO CITY OF HERCULES

Toxic Substance	Criteria for Cleanup of Hazardous Waste Substances: Industrial Land Use	Criteria for Cleanup of Hazardous Waste Substances: Unrestricted Land Use
TNT	5,000 ppm	30 ppm
DNT	200 ppm	10 ppm
DNB	500 ppm	5 ppm
Lead	2,000 ppm	500 ppm
Zinc	5,000 ppm	2,500 ppm
Copper	2,500 ppm	250 ppm
Cadmium	100 ppm	20 ppm

have resulted in localized high concentrations of heavy metals (arsenic, chromium, zinc, copper, and nickel), low pH, and PCBs at various areas in the site (26).

The site was purchased in 1977 by the Homart Development Company to be redeveloped as the multi-million dollar "Gateway Center," a combination hotel/commercial/office park development. The site came to the attention of the California Department of Health Services (CDHS) in 1980 through California's Abandoned Sites Project. The nature of the former land use suggested the presence of hazardous materials at the site and a need for an extensive site characterization effort before redevelopment. The necessary characterization was initiated cooperatively by Homart and CDHS (24).

Following full implementation with the cleanup and central strategy required by CDHS, the redevelopment of the property proceeded. A 12-story building has been erected and all substructure, including connecting roads, is now in place. The development is scheduled to be completed in 1987 (24). The information provided on the Homart site is summarized from reports by Homart's consultant, Kennedy/Jenks, and from interviews with the developer and with CDHS personnel responsible for overseeing the site characterization and remediation.

Nature and Extent of the Contamination

Homart and their consultants, Kennedy/Jenks, worked with CDHS and the California Regional Water Quality Control Board (RWQCB) in the identification, investigation, monitoring, and evaluation of the existing and potential groundwater, surface water, and soil contamination at the site. The high salinity of the aquifer underlying the Bethlehem Steel site precludes its use as a drinking water source. An investigation to assess the groundwater contamination at the site revealed minor concentrations of dissolved metals in areas formerly used as seepage basins for disposal of pickle liquors. The concentrations were not deemed to be significant in view of the salinity, and the potential for pollutant migration was judged to be severely limited (24). Samples taken as part of the initial site survey by CDHS indicated that specific areas of the 117-acre site were contaminated by PCBs, heavy metals, and/or acid wastes. The site was divided into 12 subareas for the investigation efforts. These subareas are described below:

Subarea 1: Drainage Ditch, Southeast Slag Pile, and Rebar Shop--
Heavy metals were located in the area as well as small amounts of PCB contaminated soil which may have been accidently relocated from area 12 to this area.

Subarea 2: Oil Shed Area--
This area had been used for fuel receiving and storage. Pipelines connecting with several buildings were also present. PCB contaminated wastes and soils as well as buried pipes required excavation and removal.

PCB levels in soils as high as 880 ppm were determined. Heavy metals were also present.

Subarea 3: High Voltage Tower Research Area--
This Pacific Gas and Electric (PG & E) high voltage tower research area had also been used as a dump site for slag and demolition debris. It was determined that the slag did not present a threat to groundwater quality, however, and the heavy metal-contaminated material was allowed to remain in place.

Subarea 4: Buildings and Dumping Area--
Several buildings were located in this area which was used primarily for slag and metal debris dumping. Material in the area is not a threat to groundwater quality and thus was allowed to remain in place.

Subarea 5: Oil Tank/Welding Shop Area--
A large underground oil storage tank, the main fuel supply source for the open hearth and mill buildings, was located in this area. A welding shop, facility for equipment repair and assembly, and a debris dump were also on the site. PCB contaminated oil and soil were of major concern. The highest concentration of PCBs identified in the soil and oil samples was 61 ppm; the average concentration (115 samples) was 11 ppm.

PCB contaminated oils surfaced in the area as a result of the rains in January 1982, which raised the level of the perched water table. This indicated the presence of contaminated oil in the fractured bedrock underlying the site and the need for substantial excavation.

Subarea 6: Acid Seepage Basin--
This area had been used as a holding and seepage basin for pickle liquor, acids containing heavy metals, and other liquids used in the manufacture of steel products. Field observations indicated that groundwater contamination from the acid basin was confined laterally within a radius of 100 to 150 feet from the former basin. Soil and slag excavated from the area of the basin were allowed to be used as on-site fill. The pH of soil samples taken in the area was within an acceptable range--6.2 to 7.9 although a groundwater sample from the area had a pH of 3.5.

Subarea 7: Acid Seepage Pond--
The pond (approximately 2,295 square meters or 29,000 square feet) had been used as a holding and seepage pond for waste acids and other liquids used in the galvanizing of steel products. An underground diesel tank was also present, although the contents were not classified as hazardous waste. Significant levels of nickel and copper were detected in soil samples (870 and 240 ppm, respectively), but the material was allowed to remain in place since there was no indication of migration from the site and the concentrations were below the thresholds used by the CDHS to guide the cleanup.

Subarea 8: Mill and Open Hearth Buildings--

This area contained the facilities for the manufacture of steel products. Piping materials contained one to two percent asbestos, and PCB contaminated oil and soil were present (highest concentration PCBs reported as 33 ppm). Soil samples from the area showed high concentrations of several heavy metals--8,000 ppm chromium; 4,000 ppm copper; 7,700 ppm manganese; 14,000 ppm nickel; 830 ppm lead; 500 ppm zinc; and 22 ppm cadmium. The heavy metal contaminated slag and soils were left in place or moved to other on-site locations.

Subarea 9: Open Hearth Building--

The building in this area housed facilities for the manufacture of steel and steel products. A strip of land east of the main structure contained a slag and metal scrap pile and a fuel heating station.

Soil and bricks were contaminated with heavy metals--notably, lead (as high as 11,000 ppm), zinc (24,000 ppm), copper (2,700 ppm), manganese (3,200 ppm), and cadmium (110 ppm). PCBs were also found in soil and brick samples at concentrations as high as 3,100 ppm. These materials were used as fill material in subareas 8 and 9 or were allowed to remain in place.

Subarea 10: PG & E Substation and Lab Transformer--

The buildings in this area housed the drawing and pickling shops and other facilities. PCB concentrations as high as 450,000 ppm were found in soil and oil samples taken from the area. Some heavy metal contamination was also indicated, although the heavy metal contaminated slag and soils were allowed to remain in place.

Subarea 11: Former Edwards Wire Rope Site--

The principal building on this site housed the facilities for the manufacture of wire rope products. Included were wire mills, furnace areas, a galvanizing and cleaning area, an annealling pit, a fuel oil shop and other facilities. PCBs in extremely high concentrations were present in the area (averaging 21,000 ppm for 59 oil and soil samples). Heavy metals were also present in significant concentrations. Lead was detected as high as 32,000 ppm and averaged 4,800 ppm in 16 soil and oil samples.

Heavy metal contaminated soils were allowed to remain in place. In addition heavy metal contaminated soils from the Bethlehem Steel site were placed in this subarea. Small amounts of PCB contaminated soil from subarea 12 may have been accidently relocated to this area, but it was not required to be removed.

Subarea 12: Debris Pile--

This uncontrolled debris fill area used by Bethlehem Steel was discovered during mass grading of the site in January 1982. The debris consisted primarily of wood, structural metal, tires, and other nonhazardous materials. Some oily material was also found which contained hazardous levels of PCBs. Some material, less than 7.6 cubic meters (10 cubic yards), containing approximately 114 ppm of PCBs may have been inadvertently placed as fill material on subareas one and 11. In addition to the PCB contamination, some heavy metal contamination was also present in the debris.

Site Remediation

The remediation strategy agreed upon by CDHS, RWQCB, and Homart was intended to contain the majority of contaminated materials on-site, due to the large volumes involved. Placement of the materials was determined by the groundwater contamination threat perceived for different subareas of the site. Generally, the plan called for relocation of contaminated soils to the south end of the site, in areas known to be underlain by at least ten feet of "impermeable bay mud." The soils were then capped by 30.5 centimeters (1 foot) of clean, compacted fill.

The remediation agreement stipulated that the location of the soils be clearly designated on a site map and that these areas not be excavated or substantially disturbed in the future without CDHS approval. A restrictive covenant effective into perpetuity was placed on the deed to the property as a way of enforcing these provisions over time. The deed restriction, which transfers to all future owners limits the site to commercial, light industrial, office park and hotel uses. Also the 30.5-cm (1-foot) cover must be maintained.

The cleanup itself was conducted in compliance with California/OSHA health and safety requirements relating to hazardous waste cleanups. A total of 561 cubic meters (735 cubic yards) and 143,920 liters (37,995 gallons) of hazardous material was taken to approved off-site disposal sites. No estimate is available for the extent of the contaminated soils encapsulated on-site.

Some 344 cubic meters (450 cubic yards) of PCB contaminated wastes were removed from the oil shed area (Subarea 2). The contents of the oil storage tank (Subarea 5) were removed. Oil sludge from the tank was loosened by hydrojetting; the sludge and water were treated as hazardous waste. Visibly contaminated soil and oil around the welding shop were also removed from the site. The concrete portions of the oil storage tank were not contaminated with PCB's and were allowed for use as on-site fill.

In an effort to remove the PCB-contaminated oils from the fractured bedrock underlying the oil storage area (subarea 5) the site was trenched and dewatered. The effluent was fed to an oil/water separator prior to off-site disposal. Extensive excavation to remove all oil-contaminated soil followed. After treatment with adsorbents to remove oily residues, much of the excavated material was returned to the site for use as fill. Approximately 128,883 liters (34,025 gallons) of liquid wastes and 23 cubic meters (30 cubic yards) of contaminated soil and other material were required to be disposed off-site as hazardous waste (27).

A total of 131 cubic meters (172 cubic yards) of material from the mill and open hearth buildings (Subarea 8) and 25 cubic meters (33 cubic yards) of containers of asbestos and PCB-contaminated piping and oils from the open hearth building (Subarea 9) required removal to off-site hazardous waste disposal facilities. PCB contaminated transformers and other materials from the PG and E substation and transformer area (Subarea 10) were required to be disposed as hazardous waste. Materials contaminated with PCB's in excess of 500 ppm required disposal at a special facility permitted to receive this class of waste. Wastes containing less than 500 ppm PCB's were disposed in a Class I site in California. A total of 14,886 liters (3,930 gallons) of materials classified as hazardous waste were removed from the former Edwards Wire Rope site (Subarea 11).

Some 38 cubic meters (49.5 cubic yards) of hazardous waste (including all the PCB-contaminated material from the debris pile (Subarea 12) was removed to an off-site hazardous waste facility. Approximately 290 cubic meters (380 cubic yards) of material contaminated with heavy metals was removed along with other debris from Subarea 12 to other on-site locations.

Criteria for Cleanup

During the major time period that hazardous waste cleanup took place at the site, the August 1979 and October 1982 versions of the Draft California Assessment Manual for Hazardous Wastes (CAM) were the guideline documents used by CDHS to establish the concentrations at which specific toxic substances would be assessed as hazardous (26).

PCB-contaminated soils and oil that exceeded the CAM Standards in effect at the time of the cleanup were required to be removed from the site. The threshold PCB concentrations used as criteria for cleanup were 50 ppm as a total concentration in soil and 7 ppm in oil.

Soils contaminated with heavy metals and metallic slag were considered on a case by case basis. Most of the low pH and heavy metal contaminated soils were judged to be acceptable fill material since the potential for leaching was very low. In general, these materials were allowed to remain on-site (26).

BOLSA CHICA SITE, HUNTINGTON BEACH, CALIFORNIA

Site Location and special Characteristics

The site, formerly known as the Boucher Landfill, is located on the east side of Bolsa Chica Street in the City of Huntington Beach, California. The 5-hectare (12.5-acre) site overlooks a wildlife refuge and the Pacific Ocean to the west. Surrounding land use is single-family residential in all directions.

Land Use History and Redevelopment Objectives

Following gravel mining in the 1930's, refinery sludges were dumped at the site without permit. Uncontrolled industrial dumping occurred for a long period of time. Southern portions of the site contained acid sludges from the production of high octane gasoline, while the eastern pits on the site contained alkali sludge materials, according to a 1950 report on pollution in this area. The site was owned and used by the military during World War II. Groundwater quality was noted to be poor as early as the 1950 report, probably from salt water intrusion. Drilling muds were deposited on the site beginning in 1953.

A Class III landfill was authorized at the site in 1963. Disposal after 1963 was restricted to inert solid waste materials such as earth, rock, glass, concrete, etc. The volume of refinery sludge already present on the site by 1963 was estimated to be 1,527 cubic meters (2,000 cubic yards). Some 50 small wells had been closed in the Bolsa Chica Mesa area by 1970, with 12 closings attributed to materials dumped in the former gravel pits. The County informed Bolsa Chica Community Water Company in 1971 that well water being drawn from that area was unfit to drink.

In 1979, the Mola Development Corporation, intending to build condominiums on the site, filed applications for a Tentative Tract and Conditional Use Permit. Because of complaints by neighbors, the city asked the regional office of the California Department of Health Services (CDHS) for information regarding possible contamination. Soil samples were taken by CDHS and negotiations commenced with the developer. A thorough site investigation by CDHS located pools of toxic materials and a leachate plume extending 61 meters (200 feet). Despite these findings, Mola indicated a willingness to pay the costs to clean up the site for redevelopment as condominiums.

Since cleanup was completed in 1981, 288 condominium-style residential units have been constructed at the site. Prices on the units range from $69,000 to $130,000 (24). Underground garages for the condominiums have been constructed to take advantage of the excavation (required for site remediation) and leave the residences more or less level with the surrounding terrain. Four main structures are located above the parking garages, and two conventional buildings have parking located in these underground structures.

Information on the Bolsa Chica site has been compiled from information made available by the CDHS from their files pertaining to the site characterization and mitigation.

Nature of the Contamination

Some of the materials on the surface were highly acidic and concentrated. Materials was described as "oozing to the surface" in some locations. Buried material seemed to have the strongest odor. A site analysis by the research laboratory that examined soil samples resulted in the following characterization:

> "There appears to be two or three distinct types of materials. The first type of soil appears to contain mostly aliphatic hydrocarbons with some phthalates and minor levels of other priority pollutants. Below this first level is the second type of soil which, in addition to the aliphatic hydrocarbons, contains a significant level of thiophene-type compounds plus some aromatic amine compounds similar to quinoline. A third type of material is found ponded at the surface with large quantities of hydrocarbons plus a slightly higher level of aromatic compounds than in other samples. Most of the contaminants found on-site were of an acidic nature relating to the petroleum refining industry." (28)

The site was known to give off methane gas, a product of organic waste decomposition. It was estimated that one-half the landfill area exceeded the lower explosive limit for methane. Odor problems were very apparent, resulting primarily from mercaptans and thiophenes released from the refinery sludges. The water table in the area is only about 12 meters (40 feet) below the surface. Groundwater recharge policies of Orange County have been instrumental in raising the water table in recent years, and there was some concern that the rising water table may increase the potential for groundwater pollution.

Site Remediation

Several options were considered by the developer and the State for adequate remediation of the site. These are described very thoroughly in the report prepared by the Developer's consultant, Jack Bryant Associates. Mitigation measures were needed to address:

- Soil contamination
- Vapor generation
- Vapor migration
- Odors
- Leachate migration

Options that were considered included the following:

- No remediation
- Soil flushing/in-situ detoxification
- Microbial inoculation
- Impermeable barrier/gas control system
- Conversion to inert material (stabilization)
- Thermal processing

- In-Situ Grouting
- Excavation and burial at new site
- Odor control

The resulting set of potential mitigation options and the environmental problems to be addressed provided an approximate ranking of all options. Representatives of cognizant agencies agreed that complete removal of the hazardous materials on-site and disposal of the materials at a Class I landfill site would be the most feasible and acceptable method of mitigating long-term groundwater, vapor, and soils impacts. The odor problem during excavation was felt to be unavoidable.

During the excavation, the CDHS regional office had staff on-site every day to monitor the excavation and to sample the extent of contamination remaining. A total of 45,800 cubic meters (60,000 cubic yards) of contaminated material were removed and taken to a Class I disposal site. Backfill was brought in and compacted, and sampling devices were left in place. Costs of the remediation effort exceeded $5,000,000. The excavation phase of the work was completed in July 1981.

One issue complicating site mitigation was the decision by BKK, the operator of the landfill receiving the hazardous waste, not to allow trucks to dump unless there was a cover of 15 centimeters (6 inches) of clean soil deposited on top of the waste. The landfill was the subject of publicity due to the opposition of residents of West Covina, California, to the disposal there of "carcinogens and materials hazardous to their health."

Criteria for Cleanup

The California Assessment Manual (CAM) standards combined with evidence of potential hazard due to toxicity, explosivity, and odors were used as criteria to guide the site cleanup. Also, all material with pH of less than 2.0 was removed.

The CDHS, the Regional Water Quality Control Board, and the South Coast Air Quality Management District participated in developing and implementing the cleanup plan. Because the intended reuse of the site was residential, very stringent criteria were imposed for cleanup.

DHS concluded from the site investigation and analysis that the black petroleum-like material in the fill was a hazardous waste. The material contained several classes of organic compounds at concentrations judged to be significant. These classes are--

- phenols and chlorinated phenols;
- polynuclear aromatic hydrocarbons (PAHs);
- nitro aromatic compounds;

- chlorinated ethers;
- nitrosamines;
- thiophenes;
- aromatic hydrocarbons; and
- chlorinated hydrocarbons.

In addition to the organic constituents of concern, lead was detected at levels exceeding 50 ppm, the state's criterion in effect at the time of the site investigation. (Note that the Soluble Threshold Limit Concentration (STLC) for inorganic lead is now 5 ppm, and the Total Threshold Limit Concentration (TTLC) is 1,000 ppm.) (See Section 4.)

The extent of the excavation and removal of the material judged to be hazardous was based on extensive chemical analyses of wastes and soil. Samples were taken from 20 boreholes drilled at strategic locations on the site. Solid/sludge samples were analyzed for aliphatic hydrocarbons, aromatic hydrocarbons, chlorinated organics, heavy metals, and PCB's. Well vapor samples were analyzed for aliphatic and aromatic hydrocarbons, chlorinated organics, organic lead, mercury, selenium, organic sulfur, and hydrogen sulfide.

Groundwater in the vicinity of the site was also sampled and analyzed. Following completion of the cleanup effort, a letter dated July 30, 1981 advised the Mola Development Corporation that the Department of Health Services no longer considers the subject property as a potential "hazardous waste property."

KELLOGG TERRACE, YORBA LINDA, CALIFORNIA

Site Location and Special Characteristics

Kellogg Terrace is a recently completed residential condominium project on a 8.5-hectare (21-acre) site in Orange County, California. Specifically, the site is at the intersection of the Imperial Highway (90) and Kellogg Drive in the community of Yorba Linda. These two major transportation arterials border the site on the south and west. To the north and east, the site is bordered by single-family residential land use.

The information provided on this site has been compiled from reports and memoranda from the California Department of Health Services (CDHS) files pertaining to Kellog Terrace. Included are pertinent correspondence between CDHS, the Gfeller Development Company (and consultants), the California Regional Water Quality Control Board, and the County of Orange Human Services Agency.

Land Use History and Redevelopment Objectives

The site was owned and operated throughout the 1930's as a sand and gravel extraction facility by the Yorba Gravel Company. In 1940, after all usable material had been extracted, this company attempted to sell the property for use as a petroleum refinery waste disposal area. The purchaser made a downpayment on the site and shortly thereafter began to deposit there large quantities of refinery sludge. This dumping continued until July 1941 when, as a result of odors emanating from the site, neighborhood residents successfully petitioned the Orange County Board of Health to prohibit further dumping at the site.

With the refinery sludge dumpings prohibited, the Yorba Gravel Company resumed possession of the property. In 1945 and 1946, they were allowed to use the site for disposal of used rotary drilling mud. In 1947 this dumping also was stopped to permit investigation of the site by the California Department of Health. A well 518 meters (1,700 feet) to the south of the site had become contaminated with petroleum refinery sludge. An investigation of the site revealed that at least 227 cubic meters (8,000 cubic feet) of refinery sludge had been deposited in the former quarry, and it was concluded that this refinery waste was the source of the contamination of the well to the South. In spite of these findings, however, no cleanup action was undertaken at that time.

In 1979, the Gfeller Development Company purchased the site and initiated development of the site for condominiums. This began a 2-year dialogue between Gfeller Development Company and the CDHS concerning removal of the refinery wastes deposited on the site.

Today, a 224-unit residential condominium complex of one- and two-story structures occupies the site. Gfeller Development Company indicates that no difficulties were experienced in selling all units at prices equal to those of comparable units in the area.

Nature of the Contamination

Surface and subsurface exploration of the site performed for the developer by G.A. Nicoll and Associates, Inc. (31, 32) revealed that petroliferous waste material was dumped into a low swale along the top of the hill near the center of the southwest property line. Contaminated soil was exposed in a small depression near the center of the hill. The hill where the refinery waste material was located was 7.6-13.7 meters (25-45 feet) above the adjacent freeway grade along the southwest property line. The site consisted predominantly of terraced deposits of sand and gravel. These deposits were overlain by fill, waste, and contaminated fill over a part of the hilltop. To characterize the nature and extent of the contamination, nine borings and 24 test pits were excavated on the hilltop.

The refinery waste was described as a hard black coal-like substance with a very strong odor. Chemical analyses of the refinery waste taken from the site revealed elevated levels of lead (210 ppm in one sample) and arsenic (11.6 ppm in one sample). Benzene, toluene, and xylene were also reported to be present in significant quantities. Contaminated fill was typically a silty clay impregnated with oily waste, sometimes with a slight odor. Contaminated alluvium was gravel and sand stained with the waste. Toluene and xylenes were detected in six of seven soil samples taken at various depths and locations near the refinery waste deposit. Xylene in the contaminated soil ranged from less than 0.01 to 0.49 ppm. Toluene ranged from less than 0.01 to 0.42 ppm.

The material considered by the CDHS to be hazardous included the refinery waste material as well as contaminated soil above and beneath the buried waste. Prior to the excavation, it was estimated that approximately 7,633 cubic meters (10,000 cubic yards) of contaminated fill and alluvium and 3,206 cubic meters (4,200 cubic yards) of waste would have to be removed.

The Water Resources Control Board concluded that the vertical spread of the contamination did not extend beyond 6 meters (20 feet) below the waste material. Based on the preliminary drilling logs, groundwater in the area is at least 15 meters (50 feet) beyond the lowest point of soil affected by the waste.

Site Remediation

The only remediation option considered for this site was removal of all material found by CDHS to be hazardous. This material was trucked 250 miles to the Kettleman Hills Class I hazardous waste disposal site operated by Chemical Waste Management. Remediation consisted of removing a covering of uncontaminated fill from most of the area, removing a layer of soil that had been contaminated through contact with the waste material, removing the waste material itself, and then removing the layer of contaminated material directly beneath the waste material.

Monitoring of the exposed workface for benzene and sulfur dioxide was conducted throughout the 5-day excavation in October of 1981. Water and soda ash were sprayed on the workforce to help restrict emissions. Total hydrocarbons and wind speed and direction were also monitored. This type of monitoring was also conducted at the property boundary. Operators at the site were provided with tank oxygen during two days of the excavation.

A total of 7,023 cubic meters (9,200 cubic yards) of contaminated material designated as hazardous was removed during the course of the excavation and trucked to Kettleman Hills. Uncontaminated fill containing construction debris and fill which had been deposited in the old quarry settling ponds was excavated and placed in the bottom of the deepest portion of the on-site fills.

The principal problem encountered during the site remediation work was that of odor from methylthiophene which was released whenever the waste material was exposed. Area residents were able to call in complaints about the odors given off by the waste to a special hotline. Many complaints were phoned in during the excavation. Students were kept inside at several area schools, and sports events were rescheduled due to odor problems. A public hearing was held after excavation had been completed to answer questions regarding the waste removal operation.

Criteria for Cleanup

The refinery waste and obviously contaminated alluvium from the site were determined by the CDHS to be hazardous based on the presence of lead, benzene, toluene, and xylene. This hazardous designation apparently was not questioned by the parties concerned in spite of the limited chemical analyses reported. Gfeller was advised early in the development planning that the material would have to be removed to a Class I Landfill, and he readily compiled.

The extent of the contamination to soils adjacent to the waste was somewhat more of an issue. In the end, the decision as to which materials were sufficiently contaminated to be designated as hazardous was left to the discretion of the on-site representative of the CDHS. Prior to the excavation limited chemical analyses of soil samples believed to be "uncontaminated" or "slightly contaminated" were performed. One of the soils contained lead at 53 ppm, a level only slightly above the CAM standard of 50 ppm as a Total Threshold Limit Concentration (TTLC). [Since this site remediation was completed, the TTLC for lead has been adjusted upward to 1,000 ppm. See Section 4.]

Because of the noxious odors released during the excavation, expediency in the soil removal effort was essential. Under these conditions, it would be highly impractical to analyze marginal soil samples during the course of the excavation to determine whether contaminant levels exceeded some predetermined value.

During the removal operations, for the protection of site workers and neighbors, Engineering-Sciences, Inc. (ES) was contracted by the developer to provide on-site air quality monitoring. ES continually monitored the downwind boundary of the site for benzene and sulfur dioxide emissions released from the excavation workface. These were the volatile components of the waste believed to present health hazards to people. Acceptable levels of benzene and sulfur dioxide were to be less than one-tenth of the time-weighted average occupational exposure recommendation. (See Section 4 and Appendix B.) The action levels adopted for the cleanup operation were 1 ppm for benzene and 0.5 ppm for sulfur dioxide at the site boundaries. When one of these values was approached in air samples taken at the site boundaries, measures were taken at the workface to arrest the emissions by backfilling or spraying with soda ash solution. (33)

MIAMI DRUM SERVICES SITE, MIAMI, FLORIDA

Site Location and Special Characteristics

The Miami Drum Services (MDS) site is an inactive drum recycling facility located at 7049 N.W. 70th Street in Miami, Florida. The site is 0.5 hectare (slightly greater than one acre) in size and is located in a predominantly industrial area.

Of special significance is the fact that the Biscayne Aquifer is only one meter below the natural ground surface at the location of the MDS site. The Biscayne Aquifer is the only source of freshwater available as a drinking water supply for the two million inhabitants of Dade County which includes the City of Miami. It is a highly permeable (limestone and sandstone), unconfined, shallow aquifer which underlies the entire county. At the location of the MDS site, the base of the aquifer is approximately 28 meters below natural grade. The only recharge to the aquifer is rain. MDS operations were within the cones of depression of several public well fields operating in the area.

Land Use History and Redevelopment Objectives

The Miami Drum Services (MDS) facility operated for 15 years as a chemical drum recycling center until June 1981 when it was closed by court order. Soon after closing it was purchased by Dade County (along with other adjacent properties) as the location for a maintenance facility for the Metro Dade County Transportation Administration's rapid transit system. Today the land formerly associated with Miami Drum Services is covered with rails and is used as a storage yard for commuter rail vehicles in need of maintenance or repair.

Nature and Extent of the Contamination

During the 15 years of its operations, MDS handled thousands of drums of various wastes, including corrosives, solvents, phenols, and toxic metals. Drums were washed with caustic cleaning solutions. These solutions, along with drum residues of solvents, acids, and heavy metals, were then disposed on-site. As many as 5,000 drums of various chemical wastes were on-site while the company was operating. Spills from these drums contaminated surface soils at many locations on the site. Groundwater beneath the site was also affected by the leaching contamination.

Immediately prior to cleanup activities, the site contained between 400 and 500 empty 55-gallon drums stored above ground. Some of these drums probably contained waste residues (34). Spills from these drums had contaminated soils in some locations to a depth of several meters. Except for some scattered grasses, vegetation at the site was generally destroyed.

Soil samples retrieved from ten bore holes and water samples from five monitoring wells were analyzed for EPA Priority Pollutants and other compounds. Analytical results based on soil samples collected in July 1981 from a maximum depth of 3 meters (10 feet) indicated high concentrations of phenols, heavy metals, oil and grease, and pesticides. The zone of contaminated soil extended beyond the property lines of the old drum recycling facility. Low lying areas on the property that received the runoff from the drum-washing operations were subject to the highest and deepest levels of contamination. Water in the top few feet of the Biscayne Aquifer at the site also showed contamination with phenols, oil and grease, cyanide, and volatile organics (35). Highest soil and water concentrations reported from this initial study are listed in Table 4.

The potential for leaching of contaminants off-site or to groundwater were complicated by the 55 to 60 inches per year of rainfall typical for Dade County. There were no natural or man-made barriers at the site to contain the existing contamination. Because of the polluted groundwater (levels of five metals exceeded the maximum allowable concentration for public drinking water supplies) and because of the continued leaching of contaminants from the affected soil, a cleanup action was initiated.

Site Remediation

In December of 1981, the U.S. EPA contracted with Ecology and Environment, Inc. to determine the best method of remediating the surface contamination of the MDS site. It was determined that soil excavation and off-site disposal would be cost-effective. The excavation was designed to remove all "heavily contaminated" soil from the site. Accordingly, a total of 7,335 cubic meters of hazardous debris and contaminated soil were excavated and removed from the MDS site. These materials were taken to the permitted hazardous waste disposal site operated by Chemical Waste Management, Inc. in Emelle, Alabama.

In addition to these excavation and removal operations, 2.5 million liters of contaminated groundwater were treated on-site. The total cost of all site mitigation work was $1.6 million.

Criteria for Cleanup

Following removal of the structures and debris, the initial soil excavation was guided by the following criteria:

-- Soils obviously contaminated as indicated by the total metals analysis were removed. If levels were in excess of ten times "minimum criteria" for groundwater, the soils were generally considered to be contaminated.

-- Soils with highly colored, oily deposits as indicated by visual inspection of corings were removed.

TABLE 4. HIGHEST CONCENTRATION OF LISTED PARAMETERS IN WATER AND SOIL SAMPLES AT THE MDS SITE PRIOR TO CLEANUP PROGRAM[a]

Parameter	Concentration (ppb) In Water	Concentration (ppb) In Soil
1, 1-dichloroethane	378	--
Cis-1,2-dichloroethylene	839	--
Chloroform	12.4	--
Trichloroethylene	959	--
Phenols	22,500	19,200
Mercury	3.2	8,170
Lead	220	695,000
Cadmium	170	154,600
Chromium	310	153,000
Arsenic	170	48,000
Nickel	210	44,200
Oil and Grease	945,000	31,300,000
Cyanide	1,200	--
Dieldrin	--	18,000
Lindane	--	140

[a] Analytical results from Wingerter Laboratories, Inc., 1820 N.E. 144th Street, Miami, Florida (1981).

-- Known locations that received runoff from the drum-washing operations were excavated.

The criterion for removal based on total metal concentration in excess of ten times "minimum criteria" refers to criteria established by the State of Florida for groundwater. These criteria are listed in Table 5.

The initial excavation involved the first 0.6 to 0.9 meters (2-3 feet) of the soil in the northwest portion of the property. Removal to depths of 2.4 to 3 meters (8-10 feet) were indicated by the core samples from four additional locations.

It was thought that virtually no contamination of the groundwater would take place from soils showing concentrations in soil extract of less than ten times the "minimum criteria." The U.S. EPA RCRA extraction procedure (developed for the EP toxicity characteristic to define hazardous waste) was used as the test protocol.* Although total metal concentration in the soil was used as a guideline in the initial excavations, final excavations were guided by the results of the extraction procedure together with engineering and scientific judgement.

Engineering and scientific judgement was a key factor in determining the extent of the final excavation. The levels of mercury in the extracts of several of the samples, for example, were slightly higher than the 1.4 microgram/liter "minimum criterion," although within an order of magnitude of the criterion. The additional excavation required to remove these marginal soils would have been extensive. Because there was no evidence of the oil deposits or the high color exhibited by contaminated soils from other locations, these marginal soils were left in place. It was determined that this approach would effectively mitigate and minimize damage to the site and provide adequate protection for public health and the environment.

KAPKOWSKI ROAD SITE, ELIZABETH, NEW JERSEY

Site Location and Special Characteristics

The Kapkowski Road Site is in Elizabeth, New Jersey, in a prime location just across the New Jersey Turnpike from Newark International Airport.

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*It should be noted that the RCRA extraction procedure was developed to define a characteristic of hazardous waste. Any waste that produces an extract (using the procedure) containing contaminants in excess of 100 times the Primary Drinking Water Standard is defined under RCRA as hazardous waste. Use of the procedure in this instance (to define acceptable levels) is not in accordance with the use of the EP intended by U.S. EPA.

TABLE 5. FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATIONS (FDER) "MINIMUM CRITERIA" FOR GROUNDWATER QUALITY

Parameter	FDER Recommended "Minimum Criteria" for Groundwater (mg/L)	Ten Times FDER Recommended "Minimum Criteria" for Groundwater (mg/L)[a]
Arsenic	0.000	0.00
Barium	1.0	10
Cadmium	0.01	0.1
Chromium	0.05	0.5
Lead	0.05	0.5
Mercury	0.00014	0.0014
Silver	0.05	0.5
Selenium	0.01	0.1

[a] These criteria were used by Dade County in the implementation of the cleanup program at the MDS site.

The entire site is 99 hectares (245 acres); approximately 54 hectares (134 acres) known as the West Area are located to the west of Kapkowski Road, and 45 hectares (111 acres), the East Area, are located to the east. The area surrounding the site is highly developed; the main uses are containerization, trucking, and warehousing. At least one large office building is located nearby.

Land Use History and Redevelopment Objectives

The site was natural marsh until the early 1950's when it became a disposal area. From the mid-1950's to the early 1970's the site was used as an uncontrolled dump site for miscellaneous solid refuse and waste oil. In 1972 the Port Authority of New York and New Jersey began leasing the site with the intention of preparing it for industrial development. In 1980, the Port Authority purchased the site from Central Jersey Industries, Inc. who had only a few years earlier acquired the site from the Cental Railroad Company of New Jersey.

The Port Authority of New York and New Jersey owns most of the property in the vicinity of the Kapkowski Road site, leasing to the various tenants. The West area of the site is slated for redevelopment as the Elizabeth Industrial Park promoted by the Port Authority Economic Development Department. The site is zoned for manufacturing and other industrial uses and will be built to suit. Port Authority financing can be extended to tenants for construction as well as equipment. Other incentives offered to future tenants are fixed reduced rate property tax for 15 years and a reduced rate for electricity. The proposed development plan for the Elizabeth Industrial Park, shown in Figure 1, seeks "maximum coverage of the site while maintaining a suburban industrial park environment."

Nature and Extent of Contamination

A layer of fill and partial surcharge fill comprises the surface of the site. This fill, varying from 0.3 to 5.5 meters (1 to 18 feet) in thickness, overlies a layer of refuse fill of 0.3 to 6 meters (1 to 20 feet). Beneath the refuse is a variable soil fill of 0.3 to 4.5 meters (1 to 15 feet). That material rests upon the organic marsh material which is up to 4.5 meters (15 feet) thick in some locations. A series of sands, clays, and silts underlie the organic deposits. Shale bedrock beneath these materials is 15 to 29 meters (50 to 94 feet) below grade.

The water table aquifer, 2.1 to 10.4 meters (7 to 34 feet) below ground surface, is in the refuse and overlying sand fill. This aquifer is affected by rainfall and runoff. An intermediate aquifer is present in the underlying grey sand, and a deep aquifer is located in the Brunswick shale some 15 to 27 meters (50 to 90 feet) below ground surface. The elevation of the water table varies widely over the site, with a high ridge located in the West Area.

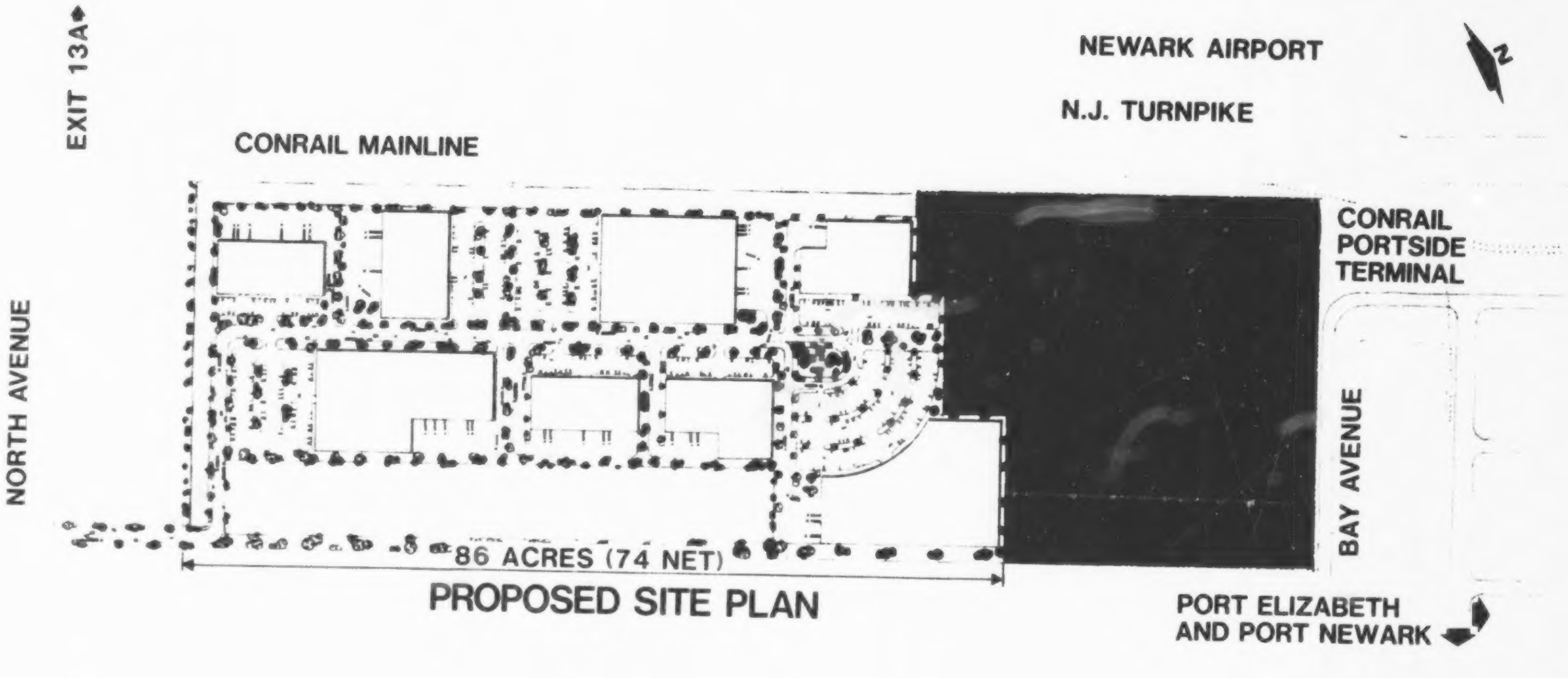
NEWARK AIRPORT
N
N.J. TURNPIKE
EXIT 13A
CONRAIL MAINLINE
CONRAIL PORTSIDE TERMINAL
BAY AVENUE
NORTH AVENUE
86 ACRES (74 NET)
PROPOSED SITE PLAN
PORT ELIZABETH AND PORT NEWARK

Figure 1. Elizabeth Industrial Park, Elizabeth, New Jersey

Prior to its initial leasing of the site in 1972, the Port Authority in 1971 commissioned an engineering consulting firm to undertake a preliminary investigation of the site. This investigation revealed a mixed fill consisting of large volumes of paper, and varying quantities of wood, metal, glass, rags, plaster, building debris, rubber tires, ashes, and soil. No oil was discovered on the site at that time.

In 1972, the Port Authority began preparation of the site for industrial development. This work included construction of a system of underdrains to facilitate consolidation of the compressible subgrade materials. The underdrains for the West Area discharged into a ditch draining into the Elizabeth Channel. The underdrains for the East Area discharged into a culvert draining into Newark Bay.

Following installation of the underdrain system, waste oil was discovered draining into the ditch on the west side of the site. In the summer of 1976, the U.S. EPA notified the Port Authority that this discharge of waste oil into the drainage ditch would have to be controlled. Accordingly, in October of 1976, a plan was developed for installation of an oil/water separator, and a contractor was engaged to remove oil that had already discharged into the ditch.

In November of 1976 samples of water taken from the ditch were analyzed. This analysis showed only low-level concentrations of some heavy metals. The Port Authority states:

> "...at that time, there was no regulatory requirement to analyze the samples for PCB's nor was there any reason to suspect the presence of PCB's on the site. Therefore, no tests for PCB's were conducted." (36)

However, an environmental test program carried out in 1981-82 has revealed the presence of PCB's in both the East and West areas of the site. In the West Area, oil was found in 19 monitoring locations, with PCB's positively identified in the oil from 16 of these locations. Concentrations in the oil ranged from 110 ppm to a high of 4,813 ppm. Oil from samples of the refuse layer also contained PCB's. Oil containing PCB's (61 to 824 ppm) was found at four monitoring locations in the East Area. No PCB's were found in any of the water samples. (36)

Results of the test program indicate that the PCB's exist in the oil which is floating on the upper surface of the water table, and adhering to the materials in the refuse layer. The oil appears to be located primarily in the northerly third of the West Area with a secondary area located in the southerly portion of the site on both sides of Kapkowski Road (36). It is estimated that from 3.8 to 11.4 million liters (1 to 3 million gallons) of oil are present on the site, located primarily within the West Area. There is potential for lateral movement of the contaminated oil. Visual evidence of migration of the oil off-site has occurred only in the drainage ditch along the west boundary.

Other regulated substances were detected in certain of the water samples, but not in significant concentrations. Low concentrations of benzene, toluene, and ethylbenzene probably result from degradation of the dissolved oil and grease in the water. Zinc and lead were present in concentrations up to 1 ppm. It was concluded, however,that the low level presence of these pollutants is not considered to be detrimental to any present or future use of either the water table aquifer or the local surface water. Gas discharging from the methane vent pipes did not contain significant concentrations of Toxic Volatile Organic Substances.

It is now believed that the presence of PCB-laden oil represents the major significant hazardous waste contamination at the site.

Site Remediation

Following the field investigations, the Port Authority evaluated several possible mitigation approaches. The first approach considered was excavation and proper disposal of the PCB-contaminated refuse. This approach was rejected as impractical due to the undefined magnitude of the volume of contaminated material at the site and the cost. Based on an assumption that only 10 percent of the refuse layer is contaminated and an estimated cost of $590 per cubic meter ($450 per cubic yard) to excavate, transport and dispose of the PCB-contaminated material, the site mitigation cost would be $100,000,000. In-situ treatment approaches were also considered but determined to be inappropriate for the site.

Several approaches to provide horizontal containment of the PCB-contaminated oil were considered, the most promising of which was the installation of a system of hydraulic control by means of a continuous subdrain system. The cost of construction of the subdrain system, oil recovery well, and associated oil/water separators and water treatment facilities was estimated, in 1982 prices, to be approximately $8.8 million. Other measures considered were installation of a steel pile wall or a slurry trench extending from the ground surface to an impervious subsurface stratum.

At the conclusion of a presentation to the New Jersey Department of Environmental Protection Division of Waste Management (DWM) of the above findings, it was suggested by DWM that the use of recovery wells be considered for mitigation in lieu of a full perimeter trench. The use of recovery wells was considered to be a potentially feasible solution for removing concentrated pools of free oil in isolated areas. An oil recovery well test system was subsequently constructed at the site by the Port Authority along with a test recovery trench for comparison.

The test well field installation consisted of a 1.07-meter (42-inch) diameter oil recovery well and 27 monitoring wells aligned in four rows around the recovery well at right angles to each other. A two-pump system was installed in the recovery well. The lower pump depresses the water table creating a hydraulic gradient toward the well and causing oil in the ground to flow toward the well. The oil collected in the well is pumped into storage containers by a floating heated oil scavenger. Water (actually leachate from the refuse) from the lower pump is transferred through a pipe to a 2.4-meter (8-foot) diameter precast concrete leaching tank located 61 meters (200 feet) east of the oil recovery well.

Between June 21, 1983 and September 6, 1983 a total of 418,939 liters (110,600 gallons) of liquid were pumped and 2,932 liters (774 gallons) of oil were recovered. The radius of influence of the well, though highly variable, averaged 4.6-6.1 meters (15-20 feet). Concurrently with the recovery well test operation a trench recovery test was performed. A 30.4 meter (100-foot) long trench was dug along the western boundary of the site. Collection of almost 11.4 million liters (3 million gallons) of liquid from the trench yielded only 644 liters (170 gallons) of oil.

In a Record of Decision of September 1984 (37) the State of New Jersey Department of Environmental Protection has recommended that oil recovery wells be used to recover oil from the Kapkowski Road-West Site. The oil recovery well system recommended by the State includes the installation of five new oil recovery wells in addition to the recovery well previously installed as a test system. The wells will be connected to an on-site oil/water separator. The oil will be removed and disposed of in accordance with all applicable hazardous waste regulations.

The approximate cost of the oil recovery system is estimated to be $1 million. The oil recovery operation will be allowed to cease when it is determined that all of the oil has been removed or that it is not economically justifiable to continue the recovery operation. The Port Authority will be required to submit data to the State concerning the oil recovery. (37)

The Record of Decision further requires that the collection and discharge of the wastewater from the oil recovery operation shall be in accordance with the draft permit under the New Jersey Pollutant Discharge Elimination System. A discharge to groundwater permit will also be required (37).

Criteria for Cleanup

Criteria used to guide the site assessment and development of the cleanup plan were the New Jersey Groundwater Quality Criteria Statewide (see Table 6) and the maximum concentrations of contaminants for the characteristics of EP Toxicity for hazardous waste as defined under RCRA. The groundwater criteria were compared against concentrations found in water

TABLE 6. GROUND WATER QUALITY CRITERIA STATEWIDE WHERE THE TOTAL DISSOLVED SOLIDS (TDS, NATURAL BACKGROUND) CONCENTRATION IS BETWEEN 500 mg/1 AND 10,000 mg/1: Class GW3

Pollutant, Substance or Chemical	Ground-Water Quality Criteria
Primary Statewide/Toxic Pollutants	
1. Aldrin/Dieldrin	1. 0.003 ug/1
2. Arsenic and Compounds	2. 0.05 mg/1
3. Barium	3. 1.0 mg/1
4. Benzidine	4. 0.001 mg/1
5. Cadmium and Compounds	5. 0.01 mg/1
6. Chromium (Hexavalent) and Compounds	6. 0.05 mg/1
7. Cyanide	7. 0.2 mg/1
8. DDT and Metabolites	8. 0.001 ug/1
9. Endrin	9. 0.004 ug/1
10. Lead and Compounds	10. 0.05 mg/1
11. Mecury and Compounds	11. 0.002 mg/1
12. Nitrate-Nitrogen	12. 10 mg/1
13. Phenol	13. 3.5 mg/1
14. Polychlorinated Biphenyls	14. 0.001 ug/1
15. Radionuclides	15. *
16. Selenium and Compounds	16. 0.01 mg/1
17. Silver and Compounds	17. 0.05 mg/1
18. Toxaphene	18. 0.005 ug/1
Secondary Standards	
19. Ammonia	19. 0.5 mg/1
20. Chloride	20. Natural Background
21. Coliform Bacteria	21. **
22. Color	22. None Noticeable
23. Copper	23. 1.0 mg/1
24. Fluoride	24. 2.0 mg/1
25. Foaming Agents	25. 0.5 mg/1
26. Iron	26 0.3 mg/1
27. Manganese	27. 0.05 mg/1
28. Odor and Taste	28. None Noticeable
29. Oil and Grease and Petroleum Hydrocarbons	29. None Noticeable
30. pH (Standard Units)	30. 5-9
31. Phenol	31. 0.3 mg/1
32. Sodium	32. Natural Background
33. Sulfate	33. Natural Background
34. Total Dissolved Solids	34. Natural Background
35. Zinc and Compounds	35. 5 mg/1

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* Prevailing regulations--adopted by the USEPA pursuant to sections 1412, 1415 and 1450 of the Public Health Services Act as amended by the Safe Drinking Water Act (PL 93-523).

** a) By membrane filtration, not to exceed four per 100 ml in more than one sample when less than 20 are examined per month, or b) by fermentation tube, with a standard 10 ml portion, not to be present in three or more portions in more than 20 are examined per month, or c) prevailing criteria adopted pursuant to the Federal Safe Drinking Water Act (PL 93-523).

samples taken from the site. The RCRA maximum concentrations were compared against leachate characteristics of the refuse using the RCRA Extraction Procedure. (See Section 4 and Appendix B for the maximum concentrations for EP Toxicity.)

THE COURTYARD, WINOOSKI, VERMONT

Site Location and Special Characteristics

The Courtyard is a housing project for the elderly and handicapped in an old converted warehouse at 110 East Spring Street in Winooski, Vermont. The housing project is, in part, supported by the U.S. Department of Housing and Urban Development (U.S.HUD). U.S. HUD provides mortgage insurance and rent subsidies for the project.

Land Use History and Redevelopment Objectives

Prior to its conversion into housing for the elderly and handicapped, the structure had been used by the Farrell Chemical Company (which became Folino Industries in March 1979) as a warehouse for storage of various industrial chemicals. The structure had been occupied previously by Porter Screen Company, a silk-screening firm. In the summer of 1979 Folino Industries vacated the building, and the warehouse was purchased by Vermont Associates (a subsidiary of Winn Development Corporation of Boston) who was the agent responsible for the cleanup and conversion of the warehouse. At the time of purchase, Vermont Associates was aware of the previous uses of the industrial structure and intended a complete cleanup as part of the property's redevelopment. (38)

Nature of the Contamination

The exact composition of the chemical waste at the site is not known. According to a newspaper account, Folino Industries denied leaving any toxic chemicals at the site. The only chemicals stored in the warehouse were said to be diatomaceous earth, calcium chloride, water softener, an oil absorbent, rock salt, soda ash, and sodium bicarbonate. A quantitative investigation of chemicals left within the warehouse was performed by Aquatec, Inc. of South Burlington, Vermont. The findings of Aquatec were not inconsistent with Folino's account.

However, beneath the wooden flooring of the warehouse building were found conical piles of solid chemical wastes. Presumably this material had leaked through cracks and holes in the floor as a result of occasional chemical spillage over the years. Aquatec estimated the volume of the chemicals found beneath the flooring to be between 4.2 and 7.1 cubic meters (150 and 250 cubic feet). These figures do not include the contaminated soil beneath the spills. This report emphasized as well that the material was not homogeneous, several different types of chemicals apparently having filtered through the wooden flooring over a long period of time.

The waste was found to be primarily inorganic and was water soluble. The pH values of aqueous solutions of selected samples of the materials ranged from 3 to 11 indicating the presence of both acidic and basic salts. Sodium was found to be the major cation with lower levels of calcium and magnesium. Major anions included chloride, fluoride, and phosphate. Trace metals detected in the waste included zinc, lead, cadmium, iron, nickel, copper, mercury, and chromium. Although these metals were reported to be present at ppm levels, quantitative analyses were not reported. Traces of the following organic solvents were reported to be present in the solid waste material: toluene, cyclohexanone, perchloroethylene, and 1, 1, 1-trichloroethane. Naphtha and oil were also present. Underground tanks, presumably from the silk-screening company that occupied the site before the chemical company, were found to contain naphtha.

Site Remediation

The underground naphtha tanks at the site were emptied and filled with inert material. Some 84 metric tons (93 tons) of solid inorganic waste and contaminated wood flooring were removed to a New York State disposal facility operated by SCA Chemical Waste Services. Some 15 centimeters (6 inches) of underfloor material as well as the existing wood flooring were removed. A sand bed covered by a polyethylene vapor barrier was placed over the crawl space area. This was then sealed with a 10.16-centimeter (4-inch) thick concrete slab leaving approximately 0.76 meter (2.5 feet) of crawl space area beneath the floor. A floor framing system and new plywood sub-floor were then constructed. All costs ($15,000) were paid by the developer.

Criteria for Cleanup

Criteria for the site mitigation were never expressed in terms of levels of chemicals that would be permitted to remain at the site. Rather than establish allowable levels for residual chemical contaminants, all material in any way contaminated by previous chemical operations was removed.

FRANKFORD ARSENAL, PHILADELPHIA, PENNSYLVANIA

Site Location and Special Characteristics

Frankford Arsenal is located in eastern Philadelphia on the west bank of the Delaware River at the mouth of Frankford Creek. The site is 45 hectares (110 acres) in size and contains numerous buildings and other structures that for 161 years were associated with Federal munitions research, development, and production.

Land Use History and Redevelopment Objectives

The Frankford Arsenal dates back to 1816 when it became the second of the nation's old line arsenals established during and after the War of 1812. Since then, arsenal activities have included munitions manufacture and research and development of armaments of a variety of types.

In 1976 when the U.S. Army decided to excess (close down) the facility, the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) assumed responsibility for site decontamination and cleanup. Considerable effort was devoted to establishing the degree of contamination at the site and the cost and effectiveness of alternative cleanup options. It was required that decontamination and cleanup be conducted to satisfy the requirements of the Federal Property Administration Services Act for turnover of property to the General Services Administration (GSA).

Following site remediation, there has been much discussion and planning of site reuse possibilities. The Philadelphia Inquirer indicated as early as October, 1980 that the part of the site closest to the water was intended for use as a regional marina and park to be built by the Pennsylvania State Fish Commission. Public officials indicate that development of the 7.3-hectare (18-acre) facility will cost $3 million and will be completed in 1986. Grading has been largely completed at the site and a contract has been let to install the boat ramps. Under GSA allocation policies, this tract was transferred free of charge to the State Fish Commission for development.

The Philadelphia Industrial Development Corporation (PIDC) has been responsible for promoting the site and is very proud of the success of their efforts to date. As of April 1985, some 540,000 square feet of floor space have been leased by the PIDC to tenants engaged in distribution, light assembly, and manufacturing. More than 400 workers are now employed by these tenants. Numerous civic groups were involved in disposition hearings because of the historic and aesthetic value of some of the buildings on the site. The Philadelphia Historical Commission (whose purpose is to foster investment in older, historic structures) has certifed the historic value of some 15 of the old arsenal buildings and thereby qualifying them for certain investment tax credits. The tax advantages for upgrading these buildings will make investment in them more appealing to private entrepreneurs.

A pretzel baker presently occupies one location of the site. Another part of the site is used by the City of Philadelphia as a lot for impounded vehicles. A large part of the remainder of the site has been sold to Shetland Properties of Salem, Massachusetts (a development consortium) for unspecified further developments. The developer estimates that about 100 light-industry tenants could be housed in the 185,800 square meters (two million square feet) of floor space, providing several thousand jobs.

Nature and Extent of Contamination

A comprehensive survey of the Frankford Arsenal was conducted to determine the qualitative and quantitative degree of contamination. A records search by USATHAMA revealed several areas of concern--low-level radiologically contaminated buildings, deposits of explosive/pyrotechnic residues, unknown quantities of unexploded ordnance, and inorganic chemical residues throughout some buildings. The underground waste discharge system (including sumps, traps, and drains) was of particular concern because of the suspected presence of explosives and other pyrotechnic materials. (39)

The site was sectioned into four physical areas for the purposes of the survey. Sector "A", a 4-hectare (10-acre) tract with 26 buildings had served primarily as the living quarters for military personnel assigned to the Arsenal. No evidence of contamination was found in this area. A 6.68-hectare (16.5-acre) portion of Sector "B", consisting of 26 multipurpose buildings was also certified for release as a result of the USATHAMA evaluation. Sixteen buildings within Sector "B" were found to contain heavy metal residues, and low-level radiological contamination was confirmed in one building and its sumps and sewers.

A pre-survey of the Arsenal performed by Battelle Columbus Laboratories during 1978 concluded that the contamination was restricted to certain facilities located in Sectors "B", "C", and "D".

The heavy metal residues (lead, cadmium, chromium, and mercury) in the buildings were due primarily to the lead-based paint used on the interior surfaces and to certain plating and metallurgical operations. Painted surfaces containing heavy metals pose a potential health hazard only when the paint is flaking and peeling since only then does it become available for ingestion.

Excluding the "400 Area" (discussed later), 135 buildings contained heavy metal residues. Mercury contamination found in a few buildings resulted from spills of laboratory quantities of mercury. Sumps in 23 buildings were contaminated with heavy metal residues.

The explosives residues resulted from the small-caliber munitions manufacturing and supply and from development of cartridge and propellant devices. The explosives residues were present in minute quantities (of the order of micrograms per square meter of surface area). Apart from the "400 Area" (discussed below), eight buildings were found to contain explosives residues. In addition, several hundred cannonballs were retrieved from the vicinity of the "329 Platform", and other cannonballs were lodged beneath the platform.

The so-called "400 Area", a nine-acre parcel with 32 buildings in the southeast corner of the site, was possibly heavily contaminated with explosives. The "400 Area" was used during World War II as a manufacturing and storage area for primer mixes and pyrotechnic material.

The low-level radiological contamination was due to the use of depleted uranium in the development of armor-piercing projectiles. Special nuclear materials (radium) were used for fire control instruments. The extent of the radiological contamination was grossly underestimated in the preliminary survey, due to the very low level of radiation that was permitted to remain after cleanup. The actual rad waste volume requiring decontamination was approximately 1,161 cubic meters (41,000 cubic feet).

Radiological contamination was found in twelve buildings, but only one building was contaminated with radium. Four outside areas were affected by radiological contamination from depleted uranium.

Site Remediation

Alternatives considered by USATHAMA for remediation of the site "with regard to environmental and historical impacts, future reuse of the property and cost/benefit" included the following:

- Identify degree of contamination and release the property "as is."
- Close the Arsenal and retain the property indefinitely.
- Decontaminate the radiologically contaminated areas and retain the property indefinitely.
- Decontaminate and release the property for restricted/industrial use.
- Decontaminate and release the property for unrestricted/public use.

The last alternative was selected since it provided the potential for maximum reuse of the property without restrictions while insuring that any health or environmental hazards would be reduced to the greatest possible extent.

Rockwell International conducted the cleanup within a 17-month time period at a cost of $8 million.

Explosives residues were destroyed primarily by passing a torch flame over contaminated surfaces at a rate of 10 feet per minute, with more complete burning used for explosives in cracks and in sumps. Radiation contamination was mitigated by removing all contaminated material since scrubbing was relatively ineffective. Heavy metal residues were cleaned by removing all loose or flaking paint and repainting.

Criteria for Cleanup

Based on previous historical searches and on-site surveys, "Sector "A" was "certified as clean by the Department of the Army," (38). A portion of "Sector B" was released also based on the records search combined with a technical evaluation.

Cleanness criteria were established early in the cleanup program "in order to define a firm basis for declaring the Arsenal releasable for unrestricted use" (39).

In support of the work at the Frankford Arsenal, the Project Manager for Chemical Demilitarization and Installation Restoration, Aberdeen Proving Ground, MD, requested the U.S. Army Environmental Hygiene Agency (USEHA) to provide decontamination criteria for building surfaces contaminated with heavy metals. Initially, the Agency developed two sets of rinse standards, one for buildings to be released for restricted/industrial usage and one for buildings for unrestricted usage. Later, because the rinse standards were thought not to adequately address health effects from inhalation or ingestion routes, surface residue criteria and air standards were developed which were used in the final cleanup (Personal communication, Colonel, MC Joel Gaydos, Director Occupational and Environmental Health, USEHA, Aberdeen Proving Ground, MD, February 26, 1985).

The surface residue criteria for lead is based on the Consumer Product Safety Commission (CPSC) standard for lead in paints applied to child access surfaces. This standard is 0.06 percent or 600 μg/lead/gram (600 ppm by weight). A maximum permissible daily intake of lead is recognized as 300 μg. Additional surface residue criteria were based on the maximum daily intakes for cadmium, chromium, and mercury (20, 50, and 4 μg, respectively) recognized by the U.S. EPA in establishing water quality criteria. The surface residue criteria, to be applied to samples collected over at least 1 square meter of unpainted surface, are as follows:

lead -- 600 μg/g
cadmium -- 40 μg/g
chromium -- 100 μg/g
mercury -- 8 μg/g.

For painted surfaces, the area should be cleaned and paint removed if defective. Air samples should be taken to demonstrate that recommended airborne concentrations are not exceeded. The recommended concentrations are:

Lead -- 1.5 μg/m^3
Mercury -- 1.6 μg/m^3
Chromium -- 1.6 μg/m^3
Cadmium -- 1.6 μg/m^3.

The recommended airborne concentration for lead (1.5 $\mu g/m^3$) is the U.S. EPA Ambient Air Quality Standard. The recommended airborne contamination criteria for mercury, chromium and cadmium were based on 1/30th of the 1975 work area standard of 0.05 mg/m^3 recognized by the American conference of Governmental Industrial Hygienists (ACGIH). The level for mercury is compatible with the U.S. EPA statement on an acceptable ambient concentration for mercury in the October 14, 1975 issue of the Federal Register (p. 48297)--"The Agency has determined that an ambient air mercury concentration of 1 microgram per cubic meter averaged over a 30-day period will protect the public health with an ample margin of safety."

If the airborne contamination criteria are exceeded, either additional surface decontamination should be performed or data to demonstrate that the concentrations represent background ambient air quality should be collected.

Water that is potentially contaminated may be released as surface water and runoff or as effluent in the storm sewers or the sanitary sewers. Thus two sets of criteria for heavy metals in water are necessary. For effluent in sewers, the applicable guidelines are the City of Philadelphia Wastewater Control Regulations. For surface runoff, the Delaware River Basin Guidelines were used. These water criteria are listed in Table 7.

TABLE 7. WATER CRITERIA FOR HEAVY METALS

	Acceptable Concentration	
	Sewers (mg/L)	Surface Runoff (mg/L)
Mercury	0005	0.01
Cadmium	0.1	0.02
Chromium	3 (total)	0.1 (hexavalent)
Lead	1	0.1

All sludge in sumps identified as containing heavy metals was removed to an approved landfill.

To assure that explosives were below detectable levels on surfaces, samples collected with acetone-saturated cotton swabs were analyzed for nitrocellulose, nitroglycerine, dinitrotoluene (DNT), trinitrotoluene (TNT), N-tetranitro-N-methylaniline (tetryl), cyclomethylenetrinitroamine (RDX), and pentaerythritol (PETN). Criteria for acceptability of the various explosives was based on the lowest detection limit of the instruments used for the analyses. These limits were 1 gram per mL of extract for nitrocellulose, NDT, TWT, tetryl, and RDX, 40 grams per mL of extract for nitroglycerine, and 50 grams per mL of extract for PETN. Acceptance of the buildings following cleanup by flashing or flaming was based on the laboratory results.

The burning, demolition, and excavation of the entire "400 Area" insured that live explosives were not left in this area.

Buildings with radiological contamination were decontaminated to very low levels (i.e., at or near the background levels associated with the brick and granite used for construction of the buildings).

Acceptable cleanness of surfaces, relative to radioactive materials was established by demonstrated conformance for total and removable activity as indicated in Table 8. Maximum allowable concentrations of radioactive materials in air and water were based on the criteria listed in Table 9.

Although no broad standards for residual radioactivity in soil are established, the Nuclear Regulatory Commission suggested that a soil action level of 35 pCi/gm depleted uranium above background was applicable to the Frankford Arsenal Decontamination Program. Based on 36 uncontaminated soil samples from the Arsenal and from two nearby locations, background activity was shown as 13 pCi/gm alpha and 15 pCi/gm beta. The acceptance criteria for soil contaminated with natural or depleted uranium is therefore 48 pCi/gm for alpha and 50 pCi/gm for beta (39).

CHEMICALS METALS INDUSTRIES, INC., BALTIMORE, MARYLAND

Site Location and Special Characteristics

Until their bankruptcy in August, 1981, Chemical Metals Industries, Inc. (CMI) occupied two pieces of property in the Westport section of Baltimore, Maryland. Specifically, the two pieces of property are located at 2001 Annapolis Road (Site 1) and 2103 Annapolis Road (Site 2) in Baltimore. The two sites are separated by approximately 15-20 row houses. The surrounding neighborhood is characterized by a mixture of residential and industrial land use.

The cleanup of the CMI hazardous waste sites was the Nation's first Superfund activity which included remedial action. The information provided here is summarized from the On-Scene Coordinator's Report (40). The Senior On-Scene Coordinator for the site was Mr. Thomas J. Massey of EPA Region III.

Land Use History and Redevelopment Objectives

Chemical Metals Industries, Inc. (CMI) recovered precious metals from waste chemical solutions and printed circuit boards. Site 1 (2001 Annapolis Road) was used for storage of miscellaneous solids in drums, large quantities of scrap metal and acids, and other caustic and neutral waste

TABLE 8. CLEANNESS CRITERIA FOR RADIOACTIVE MATERIALS ON SURFACES (Ref. 39)

Nuclides[a]	Average[b,c,f]	Maximum[b,d,f]	Removable[b,e,f]
U-nat, U-235, U-238, and associated decay products	5,000 dpm α/100 cm^2	15,000 dpm α/100 cm^2	1,000 dpm α/100 cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm/100 cm^2	300 dpm/100 cm^2	20 dpm/100 cm^2
Th-Nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000 dpm/100 cm^2	3,000 dpm/100 cm^2	200 dpm/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000 dpm $\beta\gamma$/100 cm^2	15,000 dpm $\beta\gamma$/100 cm^2	1,000 dpm $\beta\gamma$/100 cm^2

[a] Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta gamma-emitting nuclides should apply independently.

[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c] Measurements of average contaminant should not be averaged over more than 1 m^2. For objects of less surface area, the average should be derived from each such subject.

[d] The maximum contamination level applies to an area of not more than 100 cm^2.

[e] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally, and the entire surface should be wiped.

[f] The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 mg/cm^2 of total absorber.

TABLE 9. MAXIMUM ALLOWABLE CONCENTRATIONS OF RADIOACTIVITY IN AIR AND WATER[a]

Contaminant	Allowable Concentration (μCi/mL)		
	Air	Sewers	Surface/Runoff
H-3	2×10^{-7}	1×10^{-1}	3×10^{-3}
Co-60	3×10^{-10}	1×10^{-3}	3×10^{-5}
Zn-65	2×10^{-9}	3×10^{-3}	1×10^{-4}
Kr-85	3×10^{-7}	-	-
Ag-110m	3×10^{-10}	9×10^{-4}	3×10^{-5}
Pm-147	2×10^{-9}	6×10^{-3}	2×10^{-4}
Po-210	7×10^{-12}	2×10^{-5}	7×10^{-7}
Ra-226	2×10^{-12}	4×10^{-7}	3×10^{-8}
Th-230	8×10^{-14}	5×10^{-5}	2×10^{-6}
Th-nat	2×10^{-12}	6×10^{-5}	2×10^{-6}
U-nat	5×10^{-12}	1×10^{-3}	3×10^{-5}
U-238	3×10^{-12}	1×10^{-3}	4×10^{-5}

[a] Interpretations provided as footnotes to 10 CFR 20, Appendix B, will be used. Concentrations of radioactive materials in gaseous effluents are to be averaged on a monthly basis.

liquids. This site (a former gasoline station) consisted of a storage garage and adjoining yard.

Site 2 (2103 Annapolis Road) was the office, laboratory, and manufacturing center for CMI. This site consisted of a building housing company operations and an adjoining yard with numerous large (18,900 liters or 5,000 gallons) above-ground storage tanks. Local residents and former CMI employees indicated that precious metals refining had been conducted at this location since the 1950's.

Approximately two weeks before CMI filed for bankruptcy in August, 1981, a Maryland Office of Environmental Programs (OEP) inspector spotted the abandoned CMI operation. Subsequent investigations led State and Federal officials to conclude that immediate site remedial action using Superfund monies was warranted. Conditions were such that chemical substances abandoned on the site might react causing a fire or explosion in the surrounding residential neighborhood.

Using Superfund resources, both pieces of property were remediated and put back into public use. Site 1 (the former CMI chemical storage yard) is now a neighborhood park. Site 2 (the former CMI manufacturing facility) is now used as office and storage space by the Maryland Department of Health.

Nature and Extent of Contamination

Site 1 contained approximately 1,500 plastic and metal drums piled haphazardly on top of one another. Many of the drums were in a severely deteriorated condition. Liquids from some of the drums were leaking onto the ground. Markings on the drums indicated that at one time they contained, and may still contain, corrosive liquids, cyanide-bearing compounds, and ammonia-bearing compounds. Twenty drums were found to contain organic solvents. Four underground storage tanks were located on-site, one containing waste oil (suspected) and the other three containing gasoline and water. Organic vapors were detected in samples of soil and groundwater taken at the site. A blue-green colored material was being carried off-site in surface run-off from rainfall and was draining into storm sewers. Analysis of the liquids in the drums showed no commercially significant levels of precious metals. Soil samples were collected using a one-meter grid. Analyses of soils from the site indicated cadmium levels above RCRA EP toxicity values.*

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*It should be noted that the RCRA extraction procedure was developed to define a characteristic of hazardous waste. Any waste that produces an extract (using the procedure) containing contaminants in excess of 100 times the Primary Drinking Water Standard is defined under RCRA as hazardous waste. Use of the procedure in this instance (to define acceptable levels) is not in accordance with the use of the EP intended by U.S. EPA.

Site 2 contained 15 processing, chemical, and waste storage tanks. Some of these tanks were open. The tanks were filled with varying amounts of liquid and crystalline material.

Also on site 2 were approximately 100 drums filled with acids, caustics, salts, and wastes. Sampling of the drums confirmed the presence of cyanide- and ammonia-bearing materials and corrosive liquids. One drum containing acid was reported to be fuming. Approximately 175 drums contained solids and sludges of unknown composition.

A storage vault at the site contained 12 boxes and 12 bags of solid and powdered metals and other miscellaneous items. The metal stored in the vault was later confirmed to be zirconium which is unstable as a powder. In bar form, the zirconium metal is stable; however, a spontaneous chemical reaction may occur if it is dropped. Small quantities of reagents were found in the laboratory and laboratory storage areas. Low concentrations of hydrogen cyanide and organic vapors were detected through air monitoring at the site.

Chemical analyses of the contaminated soil samples taken from the site indicated that the material would be acceptable for disposal at a permitted hazardous waste landfill. Groundwater samples taken from monitoring wells at the site appeared bluish green in color, probably due to the presence of copper. Levels of copper in some soil samples exceeded 10,000 ppm. Lead was found at levels as high as 1,300 ppm.

Major concerns at both sites included: (1) imminent threat of fire or explosion in the residential neighborhood due to the chemical incompatibilities of the materials in the deteriorating drums, and (2) potential hazard to the public and the environment posed by runoff which could impact Gwynns Falls, a tributary of the Patapsco River.

Extent-of-contamination surveys and helicopter overflights indicated that most of the hazardous materials on the two DMI sites had not yet contributed to any off-site environmental degradation.

Site Remediation

At Site 1 (the CMI storage yard) more than 1,500 plastic and metal drums were removed. Approximately 3,785 liters (1,000 gallons) of liquids (mostly waste oil and mixtures of gasoline and water) were pumped from the four underground tanks at Site 1. After emptying, these tanks were filled with a concrete slurry in order to prevent the tanks from filling with water and to prevent subsidence in the future

The walls of the existing structure on Site 1 were decontaminated by sandblasting. All cadmium-contaminated soil on this site (based on RCRA EP toxicity) was classified as hazardous waste and removed to a RCRA-permitted hazardous waste disposal facility. Approximately 90 metric tons (100 tons) of contaminated soil and other debris had to be removed to such facilities. The rate for disposal of materials classified as hazardous was $41 per metric ton ($45 per ton). For solid waste not classified as hazardous, the disposal rate was $16 per metric ton ($18 per ton).

After removal of all hazardous materials and other debris, Site 1 was graded, capped, and sodded. The site is now a playground for neighborhood children.

At Site 2 (the CMI main operations center), approximately 5,250 gallons of acidic solutions and 8,300 gallons of basic/neutral solutions were pumped from the 15 above-ground storage and processing tanks. After careful removal of the liquids from these tanks, the tanks themselves were removed. Also, all other structurally unstable structures were removed.

In addition to the liquids from the large storage tanks, approximately 100 drums of acids, caustics, salts, and other wastes and 175 drums of solids and sludges of unknown composition were removed from Site 2 to a RCRA-permitted disposal facility.

The yard of Site 2 was paved following cleanup and surface grading in order to minimize exposure to any contaminants remaining in the soil and to minimize infiltration from rainwater. The building and yard of Site 2 are now used by the Maryland Department of Health as additional office and storage space.

All cleanup activities took place in 1981 during a two-month period between October 19 and December 18. The total cost of all cleanup and remediation activities was over $325,000. More than $200,000 of Superfund resources were committed to the sites. In addition to these funds the City of Baltimore contributed $35,000 in the form of police and fire protection during the removal of certain hazardous materials from the sites. The State of Maryland contributed approximately $90,000 in redeveloping both pieces of property into their current uses.

Criteria for Cleanup

The principal objective of the cleanup was to remove from both sites those materials that might cause fire or explosion in the residential neighborhood. Thus the initial criteria for cleanup involved the identification and removal of chemically incompatible materials and unstable materials from the sites. Later stages of the cleanup operation were aimed at eliminating all potential chemical and physical hazards from the site. Very thorough cleanup measures were deemed to be necessary due to its location in a residential neighborhood.

Soil removal at the site was guided by the RCRA EP Toxicity characteristic defining hazardous waste. Soils were determined to be hazardous and were removed if levels of metals in the extract from the test exceeded the established criteria of 100 times drinking water standards.

NEW YORK STATE ELECTRIC AND GAS CORPORATION, PLATTSBURGH, NEW YORK

Site Location and Special Characteristics

The site is the location of a defunct coal gasification plant operated formerly by the New York State Electric and Gas Corporation, Plattsburgh Service Center (NYSEG) in Plattsburgh, New York. The site covers approximately 4.5 hectares (11 acres) on the south bank of the Saranac River inside the city limits of the City of Plattsburgh.

The site consists of two parcels. The larger parcel (approximately 3.6 hectares [9 acres] owned by NYSEG) lies uphill to the south and represents the property associated with the defunct NYSEG gasification plant. This parcel is owned by NYSEG. The smaller parcel of approximately 0.8 hectare (2 acres) is a long narrow strip of land that fronts the Saranac River just downhill (to the north) of the NYSEG gasification plant. This parcel was given to the City of Plattsburgh in 1981 by NYSEG as a contribution to the City's long-range plan for recreational development of the Saranac River inside the City.

Land Use History and Redevelopment Objectives

A coal gasification plant was operated on the site from 1896 until 1960, most recently by NYSEG. (NYSEG purchased the site [and coal gas plant] from Eastern New York Electric and Gas Corporation in 1929.) For most of these 64 years, coal tar (a by-product of the coal gasification process) was placed of in unlined ponds on the NYSEG property just uphill from the Saranac River. Over the years, this coal tar migrated downhill across the property now owned by the City and into the Saranac River . This migration occurred by two routes--(1) by slow downward leaching through subsurface soils, and (2) from occasional overflow of the ponds during periods of heavy rainfall.

Upon shutting down the plant in 1960, the coal tar ponds were filled with random material and then covered with layers of cinders and ash. Other portions of the site to the west and north of the ponds (downhill toward the Saranac) were also filled and regraded at various times during and after plant operation. However, no records exist to document these on-site, land-fill operations.

Working cooperatively with the City of Plattsburgh and the New York State Department of Environmental Conservation (NYSDEC), in 1979 NYSEG retained the consulting firm Acres American Incorporated (Acres) of Buffalo, New York to study the coal tar contamination problem at the site. The initial geotechnical investigation was carried out by Acres during the summer of 1979. The results of this field work and laboratory testing, together with preliminary, alternative strategies for site remediation, were reported to NYSEG in early 1980. Following review of this work, a supplementary program of soil boring and testing was undertaken in November of 1980.

Actual site remediation (designed and supervised by Acres) occurred between September 1981 and September 1982. These activities were coordinated with the City of Plattsburgh's long-range plans for recreational development of the Saranac riverbank including the parcel given to the City by NYSEG. Today, this parcel is open to the public as part of the Plattsburg park system and is used heavily by fishermen during trout season. Further recreational development of the parcel awaits the City's acquisition of neighboring riverfront properties.

Nature of the Contamination

To define the site geology, hydrology, and area of contamination, a total of 53 boreholes were drilled across the site. In addition to these boreholes, three test pits were excavated to obtain bulk samples of the coal tar and soil for laboratory testing. In order to monitor groundwater levels across the site, 19 standpipe piezometers were installed.

The borings indicated the presence of an extremely dense till underlying the entire site. This till consists of silt and fine sand intermixed with medium-to-coarse-grained sand and gravel. The dense till appears to have served as a floor over the years halting vertical migration of the coal tar on the site. No coal tar was observed below this till anywhere on the site.

However, in the sandy soil and fill layers above this till, coal tar contamination was found over most of the site. In the area of the original coal tar ponds, contaminated soils were found as deep as 4 meters (13 feet). From this region of maximum soil contamination, the thickness of the contaminated soil gradually lessened toward the NYSEG property boundaries except that a layer of coal tar contamination extended across the City's parcel to the north and into the riverbed of the Saranac River. The data from the borings made it clear that the subsurface movement of coal tar from the ponds had been downward through the permeable sands and gravels and then laterally along the top of the till toward the river.

Along the south side of the Saranac River on the City's parcel, areas of coal tar contamination were visible on the surface of the riverbank. A dark, oily film was visible along a 152-meter (500-foot) length of the river bank just downhill from the NYSEG property. Coal tar globules were found in the river itself.

A laboratory testing program was undertaken to further characterize the contamination. Tar content (percent dry weight) in contaminated soils was found to be as high as 9.6 percent with an average content of 1.5

percent (41). Tests to determine total leachable salts in the soil/coal tar showed low concentrations of metals (although leachable arsenic was reported at 2 and 3 ppm and lead at 0.9 and 1 ppm in two samples). Determination of total leachable salts in coal tar reported for three samples showed high chemical oxygen demand (COD) and total organic carbon (TOC) at 850, 900, and 935 ppm (41). Leachable phenol was as high as 4 ppm in a coal tar sample taken from the Saranac River.

Site Remediation

Site remediation occurred in two phases. The Phase I Project focused on arresting the subsurface migration of coal tar away from the area of the original disposal ponds. The Phase II Project addressed the cleanup of the Saranac River and the City of Plattsburgh property to the north.

Phase I began in the fall of 1981 with the installation of a soil-bentonite slurry wall around the main coal tar pond area (735 feet in perimeter). This wall was everywhere keyed into the underlying impervious till which was 4 to 6 meters (13 to 20 feet) below grade in the main pond area. This main pond area was then capped with a temporary 20-mil polyvinyl chloride (PVC) liner. It was estimated that approximately 80 percent of the on-site coal tar was encapsulated within this containment cell.

Phase II remediation activities began in June of 1982 with the installation of a temporary, portable fabric cofferdam in the Saranac River. Behind this cofferdam, coal tar contamination in the riverbed was excavated in the dry. Water was pumped from the area of excavation into a triple-compartment settlement tank before being discharged back into the river. Riverbed cleanup was performed in two stages moving from upstream to downstream.

The temporary PVC liner that had been placed as a cap over the previously constructed containment cell was perforated, and the contaminated material excavated from the river was placed on top. Additional contaminated materials were placed in an area just to the southwest of the original containment cell. Later, this additional area was also surrounded with a soil-bentonite slurry wall and thus represented an enlargement (almost a doubling) of the size of the original containment cell.

After excavation of all visible contamination in the riverbed and along the riverbank, the riverbed and bank were re-established to grade with imported clean fill. To prevent continued migration of remaining uncontained coal tar into the riverbed area, a cement-bentonite cut-off wall was constructed through the clean fill for approximately 213 meters (700 feet) along the riverbank. A cement-bentonite wall was used in this area (instead of the soil-bentonite wall used previously on the NYSEG property) because a higher strength wall was considered necessary due to the City's plans for recreational development of this area.

To allow for drainage of groundwater from the area uphill from the cement-bentonite wall paralleling the river, a groundwater collection system was installed. This system consisted of a 15 centimeter (6-inch) perforated drain pipe 0.6 meter (2 feet) below grade and 3 meters (10 feet) upgradient of the cement-bentonite wall. This drain pipe discharges into a precast manhole at the midpoint of the line.

Water collected by this system will be pumped back uphill to water treatment equipment to be located in the vicinity of the coal tar containment cell. Treated ground water will be discharged into the Saranac River.

After grading the contaminated soil in the areas inside the walls of the containment cells, the cells were permanently capped with a 36-mil Hypalon liner. This liner was then covered with 15 centimeters (6 inches) of sand, topsoiled, and seeded. All site work was completed in September of 1982.

Because so much coal tar contamination has simply been contained on-site, future use of both the NYSEG and City of Plattsburgh parcels will have to be carefully guarded. Specifically, certain restrictions to on-site development have been mandated by the NYSDEC, and other restrictions have been suggested by NYSEG who will remain responsible for maintaining the slurry walls, containment cell, groundwater collection and treatment system, and monitoring network on both parcels. These are:

- Sale of the lands on which the containment cell was constructed is prohibited by NYSDEC.
- No structures or other activities may be placed or performed on the containment cell that could result in rupture to the Hypalon cap.
- All trees or shrubs will be maintained at a distance from the slurry walls such that their mature drip line will not intersect the slurry walls.
- All construction on or near the cement-bentonite partial cut-off wall and/or groundwater collection system must have prior engineering approval of NYSEG.

Criteria for Cleanup

Because of the nature of the site remediation activities undertaken, only the Saranac River bed and bank areas of the site can be argued to have been cleaned up. The coal tar contamination on the NYSEG parcel was simply tidied up and contained within slurry walled cells. Thus the cleanup criteria reported here pertain only to the areas along the bank and in the bed of the Saranac River from which coal tar contamination was excavated.

Because coal tar contamination, wherever it occurred on-site, was highly visible, it was convenient to express the criteria for cleanup of the riverbed and bank in terms of visible contamination. Thus the specifications of the scope of work drafted by Acres for the river cleanup contain the following definitions:

> Clean material shall mean all material removed from the riverbed or riverbank which does not visually contain coal tar as determined by Engineer and/or Inspector...Contaminated material shall mean all material removed from the riverbed or riverbank which visually contains coal tar as determined by Engineer and/or Inspector. (42)

These definitions, together with the judgment of the engineer and/or inspector, determined whether any given excavated material was removed to the containment areas or left along the Saranac River.

[Note: Extensive research on problems associated with the cleanup and redevelopment of former coal gas plant properties has been conducted in England by AERE Harwell Laboratory under contract to the Department of the Environment (43). Among other study results of relevance to the Plattsburgh's site is Harwell's conclusion that unacceptable coal tar contamination may remain on-site even after all visibly contaminated soil has been removed.]

AIDEX PESTICIDE FACILITY, GLENWOOD, IOWA

Site Location and Special Characteristics

The Aidex site is located in a rural area north of Glenwood, Iowa. In Army Corps of Engineers drawings the site is designated as part of Council Bluffs, Iowa. The Aidex site is the highest priority Superfund site in Iowa (44).

Land Use History and Redevelopment Objectives

This site was the location of a plant that formulated and packaged pesticides. The firm went bankrupt after a fire at the facility in 1976. The area sat idle for several years after the fire before cleanup activity was initiated. Five reuseable metal buildings remain on the site.

The Glenwood Industrial Foundation, Inc., an organization dedicated to attracting new business to Glenwood, and the Mayor of the City have investigated the possibility of another firm locating at the site. The Foundation floats bonds to encourage industrial development in the area. Confusion over ownership of the site and the extent of contamination present have delayed such plans. A likely candidate for relocation to the site is another pesticide firm with business similar to that of the former Aidex operation.

Site Remediation

A three phase cleanup was carried out at the site. First, drums and rusting barrels were picked up and moved inside the buildings. In the second phase all chemical drums and debris were removed to a permitted disposal facility. The third phase involved the excavation of buried drums and contaminated soil and removal of all contaminated material from the site.

The extent of the risk associated with locating another business at the site remains an important issue. The Kansas City Office of the U.S. Army Corps of Engineers will let a contract for the design of the cleanup for the buildings. Once the cleanup is completed, the Glenwood Foundation must clarify the condition of the property in order to secure another tenant. The criteria to be used for the cleanup have not yet been established.

GAS WORKS PARK, SEATTLE, WASHINGTON

Site Location and Special Characteristics

Gas Works Park is located on a point projecting into Lake Union in Seattle, Washington. The park occupies about 8 hectares (20.5 acres) which includes some 600 meters (1900 linear feet) of waterfront. The surrounding area is mainly industrial property.

Land Use History and Redevelopment Objectives

The Lake Union site known as Brown's point, once a popular spot for picnicking, was developed in 1906 by the Seattle Lighting Company as a gas plant. The location of the plant on Lake Union made it ideal for the barge delivery of local and imported coal (and later, oil) for gas production. Eventually the site became known as the Gas Company Peninsula, built by a slow process of filling in Lake Union with cinders, unusable coal and coke, unburned coal, and gas production wastes. The Seattle Lighting Company became the Seattle Gas Company in 1930 and eventually was made part of the Washington Natural Gas Company (WNG).

The original plant on Lake Union produced illuminating, heating, and cooking, and industrial gases for the growing Seattle community. Coke ovens were operated, and retort gas and carbureted water gas were produced. During the mid-1930's, six water gas sets were in operation with a total daily capacity of 6,600,000 cubic feet of gas (45). The by-products of the gas plant operations were ammonia, light oils (benzene, toluene, xylenes), and various other hydrocarbons, and coal tar which was refined into creosote. Coal tar and creosote produced by the Gas Company were delivered to the American Tar Company which was located on the peninsula adjacent to the Gas Company until about 1920. The Tar Company refined the coal tar into various grades of tars and pitches using steam distillation (46).

In 1937, oil replaced coal as the basis for gas production. Two single-shell oil gas generators known as Jones crackers were built in 1937 and 1938 with a total daily capacity of 6,000,000 cubic feet of gas (45). Gas was made in these units by passing oil over very hot bricks to crack the oil into hydrogen, methane, light oils, tars, and lampblack. Steam was introduced into the process to make carbon monoxide, a low-Btu gas. The gases were washed with diesel oil to remove light oils, then passed through boxes of sawdust or beech chip beds containing iron oxide to remove hydrogen sulfide and cyanides. The sulfur and spent iron oxide (containing ferricyanides) were wastes from the operation. The light oils recovered from the gas scrubbing (essentially benzene, toluene, and xylene) were further refined, washed with sulfuric acid, then neutralized with caustic soda. The acid and caustic wastes were dumped off-site. The uncondensables from the refining operation (butane, butene, isoprene, pentane, cyclopentadiene, and thiophene) were released to the atmosphere (46).

Oil-gas tars contained more asphaltene type compounds than the coal tars produced earlier and were not suitable for the products derived from the coal tars. Thus, the oil/gas tars were generally used as fuel for steam production. The tar emulsion from the Jones crackers was over 90 percent water and had to be concentrated before it could be burned. Naphthalene and related aromatic oils were collected in the condensation from this process. The naphthalene was sometimes combined with creosote oils and sold, but often simply dumped off-site.

The lampblack from the oil gas cracking operation was dried for briquetting and used to replace coke in the water gas sets. However, the briquets would often break during the firing. As a result, there was considerable waste. The lampblack production far exceeded the use, and the excess was piled next to the lake. The pile of lampblack grew to nearly 100 feet high and covered several acres (46). There were frequent complaints of odors from the plant and from the wind dispersal of the lampblack.

The company continued to produce gas until 1956, when a natural gas pipeline was extended to Seattle. After that, WNG used the site for storage and other activities. Figure 2 is an aerial view of the site prior to the undertaking of major demolition by WNG. During the plant's operation, the shoreline on the peninsula had been extended some 24 meters (80 feet) into Lake Union. Eventually the site was almost flat down to the lake edge where there was a 2.4-meter (8-foot) drop.

In 1962, the City of Seattle purchased the peninsula for development as a public park. A bond resolution passed in 1968, providing funds for park development, and planning for the park was initiated. The City hired a landscape architect, Mr. Richard Haag, to propose a master plan for the park. After a study of the site, Mr. Haag determined that traditional park development would be impractical and proposed a controversial plan which allowed for the restoration and reuse of some of the gas works structures. The plan for the site demolition (to be done by WNG in 1971 under the 1962

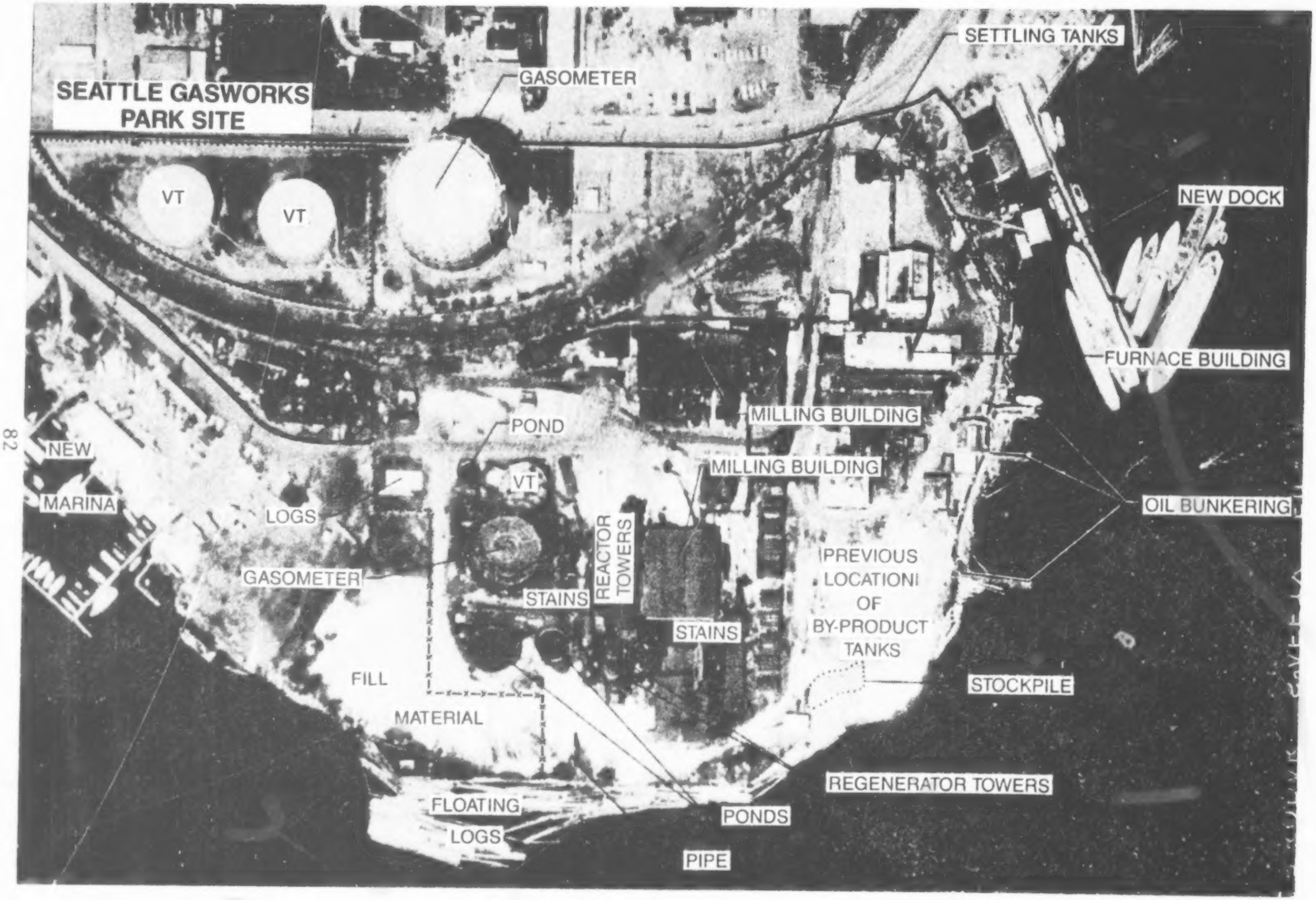
SEATTLE GASWORKS PARK SITE
GASOMETER
SETTLING TANKS
VT
VT
NEW DOCK
FURNACE BUILDING
MILLING BUILDING
POND
MILLING BUILDING
NEW
MARINA
VT
LOGS
OIL BUNKERING
REACTOR TOWERS
PREVIOUS LOCATION OF BY-PRODUCT TANKS
GASOMETER
STAINS
STAINS
FILL
STOCKPILE
MATERIAL
REGENERATOR TOWERS
FLOATING
PONDS
LOGS
PIPE

Figure 2. Aerial view of Gas Works Park site prior to demolition by WGN.

purchase agreement) called for leaving six generator towers, the pre-cooler towers, a boiler house, and an exhauster building. Mr. Haag concluded that it would not be possible to remove all of the underground piping and existing soil from the site, nor to cover the entire site sufficiently to permit the growth of large trees essential to a more traditional park design (47). Despite the controversy over allowing the former plant structures to remain, the City Council finally approved Mr. Haag's plan in 1972.

Originally, the park was to be named the Myrtle Edwards Park, after a Seattle Councilwoman who was influential in establishing the park system in the city. However, her relatives deemed it inappropriate to bear her name when they learned that original gas works structures were to remain on the site. Thus, the park came to be called simply the Gas Works Park, although the park master plan still bears the name "Myrtle Edwards Park." Another Seattle city park was later dedicated to Mrs. Edwards.

Nature and Extent of the Contamination

Some 50 years of heavy industrial use at a time when there was little concern for environmental contamination had left the site on Lake Union heavily contaminated with production residues, spills, waste materials, and air pollution fallout. Mr. Haag, the landscape architect, expressed concern for the ability of the site to support vegetation, noting that there was no "natural" soil on the site. He described the condition of the soil as a sterile layer cake of hydrocarbon contamination that supports no vegetation (47).

Studies were undertaken by the Seattle Engineering Department and by Dr. Dale Cole and Peter Machno, of the University of Washington, to characterize drainage patterns and soil conditions at the site. Cole and Machno (48) found that depths of fill material at the site ranged from 2 to 20 feet. Samples of the fill material were collected for evaluation regarding potential horticultural problems. The fill is underlain by dense glacial deposits of compacted till. This very low permeability subsurface layer directs the flow of the groundwater system and has restricted liquid contaminants spilled on the site to the surface materials. A perched water table identified in the fill above the dense till layer results from the slow percolation of water along the till surface to the permanent water table associated with Lake Union. A subsurface mounding of the till in the Southeast corner of the site was found to cause a diversion in the natural flow pattern of water toward the Lake. Oil from old spillages was found floating on the perched water table and concentrated at this level within the soil. It was concluded that this part of the Park site would always present problems if preventive measures were not taken. In a letter dated March 30, 1972 to the Project Director for the site, Cole and Machno noted a massive surface spillage of oil that occurred in the fall of 1969. The spillage was apparently covered by WNG with a thin layer of fill. Due to a seasonable perched water table, the oil floated up through the fill and again presented a surface contamination problem.

Site Remediation

This description of the remediation activities is summarized from information contained in a document made available by the site manager in the U.S. EPA Regional Office (49). The document was probably prepared in 1984.

After the removal of most of the aboveground structures by WNG in 1971, considerable site preparation work was still needed. The primary intent was to stockpile and/or bury on site much of the excavated material and demolition rubble. The stockpiling was in the central portion of the site. Portions of the stockpile were later buried on-site. Several existing structures considered potential safety hazards were removed. WNG was required to purge certain pipes in 1973.

The mound area in the southwest portion of the site consisted of excavation materials from off-site. This fill had been brought to the site during the 1960's and early 1970's. It was thought at one time that this fill material could be used to cover the entire site following the demolition of the aboveground structures. However, the "Great Mound" became a major element of the master plan for the park, and was cleared and grassed and opened to the public for the purpose of viewing the ongoing park development.

Work contracted by the Parks Department included the following tasks:

-- Demolition and burial in northwest section of the rubble from 13 concrete purifiers which were located just east of the tower area.

-- Removal and stockpiling of the contents of the purifiers (i.e., wood chips coated with iron oxide and residue from the purification process).

-- Removal and burial in the northwest section of the concrete slab remaining from the 2-million cubic foot storage holder.

-- Demolition of remaining concrete foundations and piping.

-- Excavation and removal or stockpiling on-site of approximately 20,000 to 30,000 cubic yards of badly contaminated soils.

-- Regrading of demolition areas to match the surrounding ground level.

In the process of removing contaminated material and burying rubble and debris, there was concern of increased pollution to surrounding areas, particularly Lake Union. Of particular concern was the excavation of the contaminated soil in the southwest area (48). The contract specifications cautioned the contractor responsible for this work on the conditions there. The contract stated, "Excavating oil-gas contaminated material at the southwest property edge shall be performed with extreme care. This excavation extends to the lake level and shall commence 30 feet or more inland from the water's edge. Demolition work and pipe removal shall be completed prior to any excavating of this 30-foot wide levee. When the inland area is excavated, filled and/or graded to the proposed grade, the levee at the lake's edge shall be removed."

One part of the site preparation work involved efforts to improve growing conditions by an application of a compost-like mixture containing dewatered sludge cake as the primary ingredient. The mixture was applied over approximately 10 to 12 acres of the southerly half of the site (about 100 tons per acre, wet) and then worked into the top 18 to 24 inches by periodic plowing. Sawdust and leaves were also applied and worked into the surface soil. The surface was reworked, fertilized, and sown with a cover crop of grass about two weeks after the compost treatment. The first crop was plowed under, and the area was finally rehydroseeded.

The actual park improvements were undertaken upon completion of the site preparation work. Phase I of the park development consisted of the following actions:

-- Renovation of the former boiler house for use as an indoor/outdoor picnic shelter.

-- Renovation of former exhaust building for use as a "play barn."

-- Creation of a grassed picnic "bowl" projecting to the water's edge.

-- Construction of paths.

-- Further development of an existing 170-car parking area.

-- Deter access to the towers and remove miscellaneous structures.

-- Regrade mound and hydroseed.

-- Plant trees and shrubs and provide sod in one small section of the picnic area.

The work delineated above was completed, and the official park opening was held during the summer of 1976. Additional improvements were completed in 1978. Plans for further improvements were being finalized when the U.S. EPA began an investigation of contamination at the site.

Criteria for Cleanup for Park Development

Soil testing during the park development was directed primarily at horticultural aspects of the design. The park did not include any significant amounts of fill. Cuts were made primarily in the southeast quadrant and between the mound and tower areas. Considerable soil was removed from the site, part of which was known to contain arsenic. No work was undertaken in the water areas surrounding the site.

> "It appears that the development was directed at reusing the site in what was felt at the time to be an environmentally sensitive manner. Both the general design concept and the budget were important factors in the decisions that were made. The major controversial issues centered on the retention and reuse of structures associated with the former gas plant. Most of the discussion concerning the levels of pollution centered on what would and would not grow on the site. Public health was an issue, more in terms of access to the towers, aquatic activity from the park, and use of the Play Barn than in terms of general use of the site." [Excerpt from "History of Park Development."]

Additional Investigations

In April 1984, grab samples were taken from several locations at the park site. Elevated concentrations of cyanide and polycyclic aromatic hydrocarbons (PAH's) were found. These initial EPA investigations led to a closure of the park during the three months beginning in April 1984. The Centers for Disease Control recommended restricting public access to the park on the basis of high levels of PAH found in grab samples. PAH levels were highest under the pier (7,000 ppm) and around a metal vessel sandbox (10,000 ppm at a depth of 3 - 6 feet).

After the park was closed, a total of 72 samples were taken from 24 locations (50). Samples were taken at depths of 15 and 91 centimeters (6 inches and 3 feet) and were analyzed for a variety of substances. During the investigation, respirators were provided for workers due to the high level of volatile organic substances suspected.

High levels of PAH's were found in every sample obtained, with individual species concentrations up to 620 ppm. Higher concentrations were usually found in the 6-inch composite samples. Levels were compared to goals for PAH's listed in Multimedia Environmental Goals for Environmental Assessment (MEGs) (12,13) and were found to exceed the goals by a factor of 100 in several sample locations (50). A summary of the levels of individual PAH's determined in borehole samples at 6-inch depth is given in Table 10.

Volatile organic compounds also were detected in all sample locations, with concentrations as high as 802 ppb. Benzene, ethyl benzene, and toluene, were all found, usually at low levels. In addition, a number of other

TABLE 10. SUMMARY OF PAH LEVELS FOUND IN SAMPLES TAKEN FROM 6-INCH DEPTH AT GASWORKS PARK (50)

Compound	Range (ppm)	Average (ppm)
Two and Three-Ring PAH's		
Acenaphthene	0.02 - 18	0.58
Acenaphthylene	0.05 - 83	7.2
Fluorene	0.07 - 11	1.2
Naphthalene	0.13 - 100	12.5
Anthracene	0.08 - 17	4.2
Phenanthrane	0.51 - 620	49.9
Fluoranthene	0.34 - 400	34.4
Four and Five-Ring PAH's		
Benzo(a)anthracene	0.42 - 61	16.6
Chrysene	0.32 - 110	28.7
Pyrene	0.58 - 460	70.5
Benzo(b)fluoranthene	0.43 - 410	45.5
Benzo(a)pyrene	0.88 - 190	47.4
Benzo(ghi)perylene	1.6 - 570	98.1
Dibenzo(a,h)anthracene	2.2 - 110	19.2
Indeno (1,2,3-cd)pyrene	1.3 - 450	72.3

substances, including dibenzofuran, 2-methylnaphthalene, and other tentatively identified substances have been discovered in the soil samples from Gas Works Park. Tanks left on the site in an area designated as a playground may also contain some type of product.

It was found that most samples contained detectable levels of heavy metals, and that usually the 15-centimeters sample levels were greater than the 91-centimeter levels, indicating that the metal/CN contamination was of surface origin. The levels of metal contaminants were above normal background levels but lower than the concentrations generally considered to represent a hazardous waste. This conclusion was based on Total Threshold Limit Concentrations as reported in the California Assessment Manual for Hazardous Wastes, February 1984. (See discussion and specific CAM Standards in Section 4.) Cyanide concentrations ranged between 0.56 and 458 ppm (average 31 ppm) in the 6-inch samples and 1.21 and 340 ppm (average 36 ppm) in the 3-foot samples (50).

To address the significance of the health risks associated with use of the Park, Seattle's Mayor, Mr. Charles Royer, convened a panel of public health experts and community residents to review the EPA test results, assess the health risks associated with Park use, and recommend measures to minimize those risks. The Mayor's Committee developed estimates of inhalation and ingestion exposures to benzo(a)pyrene based on reasonable estimates of the amount of soil ingested per day by children and the percent absorption of the benzo(a)pyrene (51). The panel concluded that the health risks associated with use of the Park are small, and that the only significant health risk would be posed by frequent ingestion of the most contaminated materials found in the Park over a long period of time.

The Committee recommended securing the area under the prow at the southern point of the Park and securing the "dome" on the West side of the outdoor children's play area. They further recommended that the play barn be thoroughly cleaned and former gas plant equipment be repainted. The Committee suggested that the City reinforce the policy of not permitting bathing in Lake Union and recommended followup sampling and monitoring.

The Committee's Draft Report was reviewed by the Center for Environmental Health, Centers for Disease Control (CDC). The CDC noted (52), "In the absence of sufficient data on carcinogenic dose-dependency and latency for low-dose, long-term PAH exposures, public health measures should aim to reduce or prevent these exposures wherever possible." The CDC (52) concluded that:

- Park goers should not have contact with the high levels of PAH present in (a) the sandbox, (b) the area northeast of the compressor building, (c) the play barn, and (d) any other areas shown to be similarly contaminated.

- Park goers should not have contact with coal slag in the Park.

- Additional sampling should be carried out, particularly to determine PAH contamination in Lake Union.

Recognizing the severity of the buried contamination at the Gas Works site, concern was expressed by some members of the community that opening up the soils of the Gas Company peninsula could only worsen the potential for irreversible ecological damage to Lake Union. Notable among those voicing this concern was Mr. Otto Orth, a distinguished chemist and lifelong citizen of Seattle who in 1984 recounted in a letter to the Seattle Times a history of the operations at the Gas Works.

The Gas Works Park was reopened in late summer 1984 (53) with signs posted to warn people to wash after playing in the Park and not to eat the soil. The Gas Works Park as it appeared in 1984 is shown in Figure 3. Areas of high contamination were fenced off pending cleanup. Remediation planned involves the capping of any areas of exposed slag with nylon mesh and clean soil. Also cleanup and coverage of several eroded or highly contaminated areas is planned. A permanent concrete wall will be constructed around the contaminated materials underneath the prow area. The total cost of these efforts has been estimated at $132,000. Further investigation into the possibility of contamination of Lake Union is also being planned by the City in cooperation with the U.S. EPA and the State of Washington Department of Natural Resources. If leaching from the Park site proves to be a factor in the contamination of the lake, capping with clay and clean soil will be required. Estimates of the cost of such capping range from $600,000 to $1.7 million.

QUENDALL TERMINAL, RENTON, WASHINGTON

Site Location and Special Characteristics

The Quendall Terminal site is located in Renton, Washington, a city south of Seattle. The site covers about 81 hectares (20 acres) of land on the shore of Lake Washington.

Land Use History and Redevelopment Objectives

Quendall Terminal was a refinery operated by the Reilley Tar and Chemical Company beginning about the turn of the century. The plant received coal tar by tankers from gasification plants and refined the tar into creosote and pitch for the wood processing and the aluminum industry. The products were used in the preservation of wood. The plant continued in operation until the mid-1960's.

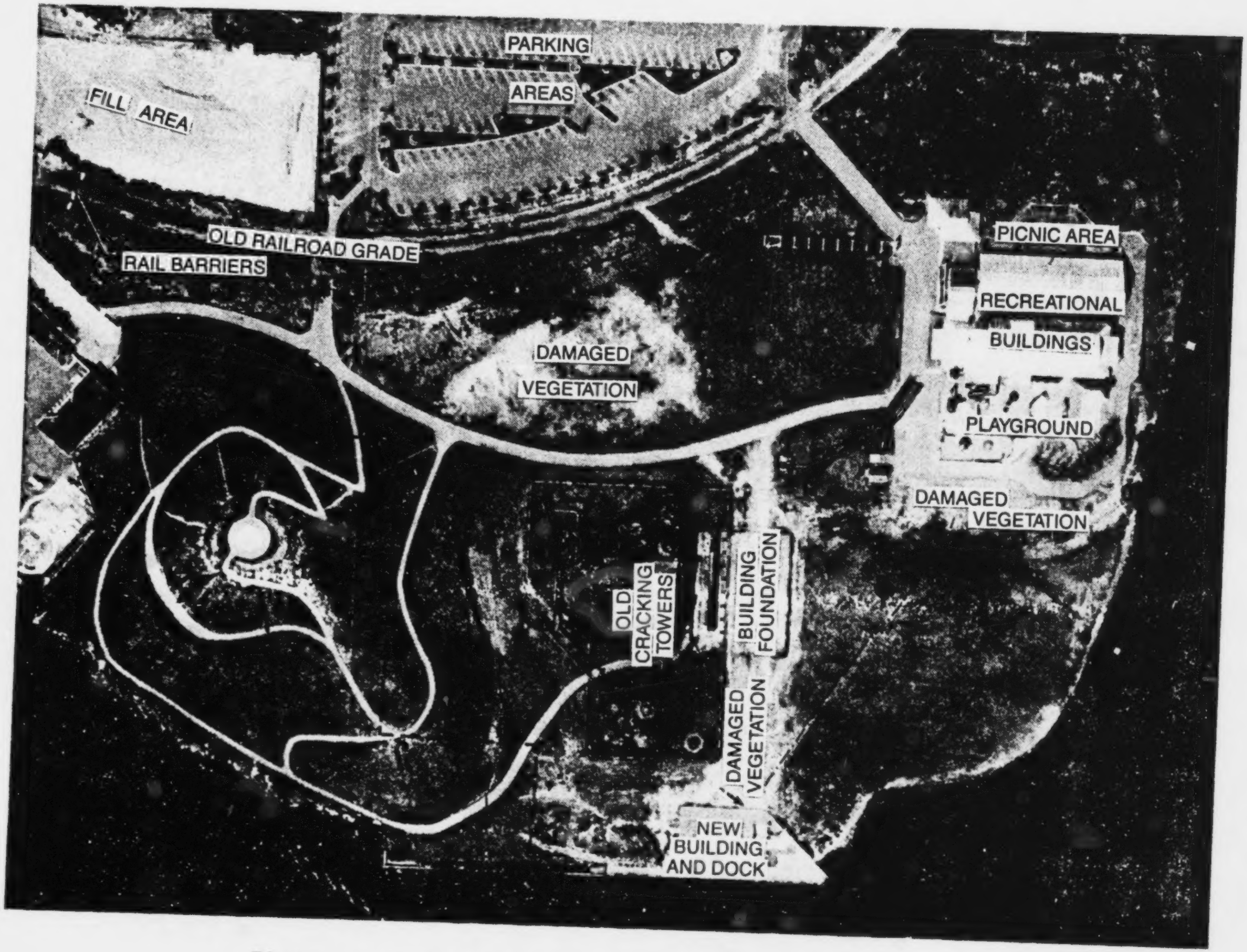
PARKING
AREAS
FILL AREA
OLD RAILROAD GRADE
RAIL BARRIERS
DAMAGED VEGETATION
PICNIC AREA
RECREATIONAL
BUILDINGS
PLAYGROUND
DAMAGED VEGETATION
OLD CRACKING TOWERS
BUILDING FOUNDATION
DAMAGED VEGETATION
NEW BUILDING AND DOCK

Figure 3. Aerial view of Gas Work Park.

In 1971, the site was acquired by a group of investors who renamed the site Quendall Terminal. The investors own the two adjoining sites, J. H. Baxter Company and Barbe Mill, and wish to control the development of the combined properties. The legal representative of the two companies, James C. Hanken, is the president of Quendall Terminal. The investment plan for the site involves the development of the Quendall Terminal site along with the J. H. Baxter property to the north and the Barbe lumber mill to the south into a development including a marina, motel, condominiums, and office buildings. The combined area will consist of about 24 hectares (60 acres). The main financial backer for the proposed development is an investor from Hawaii.

Until very recently the old storage tanks on the property were used as a source of revenue. All the buildings and tanks have now been dismantled. The site is currently used for storage and an off-shore boom that provides a source of revenue.

In 1979, a development concept for the combined properties was agreed upon, and a developer was retained for the J. H. Baxter property. In 1981, the conceptual design for the development, to be known as Port Quendall, was submitted to the City of Renton and was basically approved. The City of Renton imposed a condition that the development plan must prevent further contamination of Lake Washington in a cost effective manner.

In February 1982, a preliminary environmental impact statement was prepared for the investment consortium by CH2M Hill (54). The EIS was presented to the City of Renton. A three phased development plan to be realized over a 30-year period was proposed. The first phase would involve development of the J. H. Baxter property. The Barbe lumber mill property would be developed second. The Quendall Terminal property which lies between the lumber mill and the Baxter property would be developed last. The development of the Quendall Terminal, however, is crucial to the success of the adjoining developments. The EIS acknowledged contamination at Quendall Terminal. The City of Renton required more detail in the EIS, specifically concerning remediation plans for Quendall Terminal. In 1983, the consortium hired the firm of Woodward Clyde to propose remedial alternatives for Quendall.

Nature of the Contamination

Slag and waste from the process were landfilled in a natural depression in an old creek bed and other places on the site during the operation of the refinery. As a result of this land disposal and operations at the site, there are several areas of high contamination. When the property was acquired, the investors were aware of the possibility of contamination, and anticipated the need to remove some hydrocarbons from oil spills. There is anecdotal information concerning a tanker load of wood preservative being accidentally pumped into the lake (55).

Some limited characterization of the contamination at the site was performed in the 1960's. This investigation, though inconclusive, suggested that the contamination extended, in at least some places, down to a depth of 18 meters (60 feet).

As part of the remedial investigation, Woodward Clyde (56) installed 12 6-meter (20-feet) deep wells. Samples from these wells indicated areas that were highly contaminated. In addition, 18 soil borings were performed. Polynuclear aromatic hydrocarbons (PNA's) in concentrations as high as 4.8 percent have been found in soil and water samples obtained from certain spots. PNAs found include acenaphthene, fluorene, naphthalene, fluoranthene, pyrene, chrysene, and phenanthrene. It has been estimated that at least 165,000 cubic yards of soil are contaminated with at least 1 percent PNA. There is some evidence of migration of these substances. PNA's are not particularly soluble in groundwater; however, in the presence of some hydrocarbons such as benzene, toluene, and xylene (BTX) they will dissolve. These hydrocarbons are present in some parts of the Quendall Terminal site. There is also heavy contamination in the lake sediment just offshore, probably from spills. Analysis of sediment samples from the lake showed PNA contamination in concentrations as high as 1.3 percent (55).

Site Remediation

Because of the contamination at Quendall, the developers have altered their proposed use of the property where the contamination is most severe. The major contamination concern is related to effects on the water quality in Lake Washington. The plans for the marina have been abandoned due to the potential problems associated with dredging the highly contaminated sediment off the site.

The proposed remediation scheme for Quendall (57) involves installing a system of French drains to divert surface water and a slurry wall to prevent drainage from the site into Lake Washington. The plan also calls for a system to recover and treat groundwater from the site. Pumping would lower the water table at the shore by 0.46 meter (1.5 feet) and by 1.5 meter (5 feet) at the center of the site, where BTX is present. The treated water would be discharged to the city sewer. The entire site would be capped to limit infiltration of rainwater. Use of the property following the remediation would be limited to nonsensitive uses.

In October 1984, Quendall Terminal was among the uncontrolled hazardous waste sites proposed for inclusion in the National Priorities List (NPL). The comment period regarding the October proposal extended through December 1984. The ranking of the site according to the Mitre model was done by a contractor hired by the State of Washington. The site scored high enough to make the NPL mainly because a backup well for the City of Renton is located within a three mile radius. In actuality this subject well is not used and such a backup well could easily be relocated elsewhere.

Currently the Quendall Terminal investor group is trying to get the site off the NPL, since they are concerned that such a listing will discourage investors from considering the site. They also anticipate delays associated with bureaucratic involvement in the development schemes.

BOULEVARD PARK, BELLINGHAM, WASHINGTON

Site Location and Special Characteristics

Boulevard Park is located in Bellingham, Washington, a town of approximately about 60,000 people some 100 miles north of Seattle. The park is made up of two parcels of land, an upper bluff and a lower section along the shore of Bellingham Bay. A 6-meter (20-foot) high embankment separates the two levels of the park. On the lower edge of the embankment lies a track of the Burlington Northern Railroad. The two parts of the park are connected by a pedestrian bridge and stairs. The lower section of the park which projects into Bellingham Bay is mainly fill, consisting of construction debris, sand, and gravel.

Land Use History and Redevelopment Objectives

Boulevard Park is the site of a former coal gasification plant. The plant was constructed in 1890 and operated until after World War II, when natural gas came into use. Elevations at the site have remained basically unchanged since the gasification plant was in operation. The rail line has been in place for many years. To the north of the site the land rises sharply, so it was not likely used by the gas plant. There is no evidence that coal tar was ponded on the site, and, because of the limited land area available, it is unlikely that large amounts of tar or other residues were stored on site for long periods of time. Ash and slag may have been shipped off by rail and used in road building. It has not been determined whether or not the plant had an associated refinery for the production of by-products.

A large vertical concrete storage tank from the old gas plant remains in the upper park. The top of the tank is level with the ground on one side, and the round flat top is readily accessible. The top of the tank is the highest point in the park and has been designated as a picnic area. The land slopes sharply from the top of the tank exposing the full height of the tank toward the bay. A trail leading from the area near the top of the tank winds around the tank to the top of the embankment separating the two levels of the park.

Contamination at the site was first suggested after hazardous residues were discovered at another defunct gasification facility in Seattle. A newspaper reporter called the U.S. EPA Region 10 office to ask if Boulevard Park might also be contaminated. A subsequent investigation revealed high levels of polycyclic aromatic hydrocarbons in samples taken from the area, and as a result the upper part of the park was closed to the public on July 9, 1984.

Nature of the Contamination

When the park was constructed, the concrete storage tank apparently contained residues from the former process. Infiltrating rainwater has since raised the liquid level in the tank, and a black tarry material (presumably coal tar) now seeps from the seams of the tank and oozes down the sides, coating the walls. Upon weathering, the material appears to harden on the walls of the tank and to blister and crack.

At the foot of the embankment liquid obviously containing hydrocarbon material of unknown composition was observed seeping from a bare area near the railroad tracks.

Approximately 40 soil samples were obtained from the upper park in the vicinity of the storage tank, along the embankment, and in the lower park. The locations of the samples are shown in Figure 4. High concentrations of polycyclic aromatic hydrocarbons were found in samples from the tar seeping from the tank and in some of the soil samples (58). These substances included benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene and dibenzo(ah)anthracene--compounds which have been determined to be carcinogenic in laboratory animals. Highest levels of polycyclic aromatic hydrocarbons in samples taken from the site are listed in Table 11.

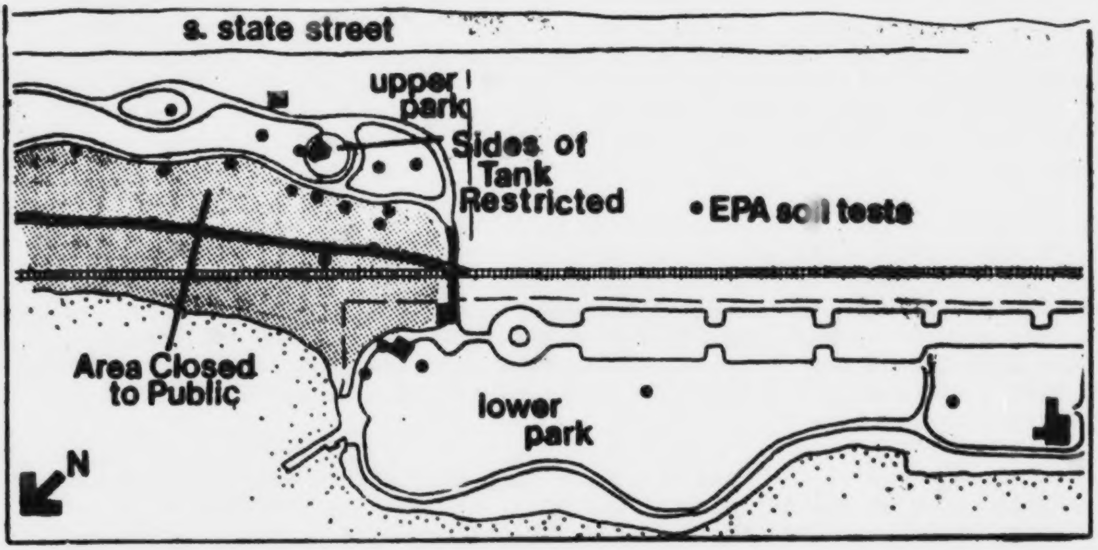

Figure 4. Boulevard Park, Bellingham, Washington, showing locations of samples taken by EPA.

TABLE 11. HIGHEST CONCENTRATIONS OF POLYCYCLIC AROMATIC HYDROCARBONS IN SAMPLES TAKEN FROM BOULEVARD PARK

	Concentration (ppm)	
Compound	Samples from storage tank (coal tar)	Samples from pathway in upper park
Anthracene	1,866	98
Phenanthrene	94,530	7,564
Fluoranthene	52,240	3,420
Benzo(a)anthracene	6,470	454
Benzo(b)fluoranthene	6,840	272
Benzo(k)fluoranthene	1,617	151
Pyrene	27,360	2,693
Chrysene	7,960	583
Benzo(a)pyrene	6,592	386

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APPENDIX A

SUMMARY OF CONTACTS

This appendix lists the various individuals contacted in the U.S. EPA Regional Offices and State offices responsible for site cleanups and environmental protection.

APPENDIX A

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APPENDIX B

EXISTING GUIDELINES USEFUL IN SITE ASSESSMENT AND CLEANUP

This appendix presents in tabular format some of the established standards, criteria, and recommendations that have been used to guide site assessments and cleanup actions.

TABLE B-1. NATIONAL PRIMARY AND SECONDARY AMBIENT AIR QUALITY STANDARDS (40 CFR, Part 50)

Pollutant	Type of standard	Averaging time	Frequency parameter	Concentration $\mu g/m^3$	Concentration ppm
Carbon monoxide	Primary and secondary	1 hr	Annual maximum[a]	40,000	35
		8 hr	Annual maximum	10,000	9
Nitrogen dioxide	Primary and secondary	1 yr	Arithmetic mean	100	0.05
Particulate matter	Primary	24 hr	Annual maximum	260	-
		24 hr	Annual geometric mean	75	-
	Secondary	24 hr	Annual maximum	150	-
		24 hr	Annual geometric mean	60[b]	-
Sulfur dioxide	Primary	24 hr	Annual maximum	365	0.14
		1 yr	Arithmetic mean	80	0.03
	Secondary	3 hr	Annual maximum	1,300	0.5
Lead	Primary	90 day		1.5	
Ozone	Primary and secondary	1 hr		235	0.12

[a] Not to be exceeded more than once per year.

[b] As a guide to be used in assessing implementation plans for achieving the annual maximum 24-hour standard.

TABLE B-2 OSHA REGULATIONS ADOPTED IN 1971

SUBPART Z—TOXIC AND HAZARDOUS SUBSTANCES

Source: 39 FR 23502, June 27, 1974, unless otherwise noted. Redesignated at 40 FR 27073, May 28, 1975.

§ 1910.1000 Air contaminants.

An employee's exposure to any material listed in Tables Z-1, Z-2, or Z-3 of this section shall be limited in accordance with the requirements of the following paragraphs of this section.

(a) Table Z-1:

(1) Materials with names preceded by "C"—Ceiling Values. An employee's exposure to any material in Table Z-1, the name of which is preceded by a "C" (e.g., C boron trifluoride), shall at no time exceed the ceiling value given for that material in the table.

(2) Other materials—8-hour time-weighted averages. An employee's exposure to any material in Table Z-1, the name of which is not preceded by "C", in any 8-hour work shift of a 40-hour workweek, shall not exceed the 8-hour time-weighted average given for that material in the table.

(b) Table Z-2:

(1) 8-hour time-weighted averages. An employee's exposure to any material listed in Table Z-2, in any 8-hour work shift of a 40-hour workweek, shall not exceed the 8-hour time-weighted average limit given for that material in the table.

(2) Acceptable ceiling concentrations. An employee's exposure to a material listed in Table Z-2 shall not exceed at any time during an 8-hour shift the acceptable ceiling concentration limit given for the material in the table, except for a time period, and up to a concentration, not exceeding the maximum duration and concentration allowed in the column under "acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift."

(3) Example. During an 8-hour work shift, an employee may be exposed to a concentration of benzene above 25 ppm (but never above 50 ppm) only for a maximum period of 10 minutes. Such exposure must be compensated by exposures to concentrations less than 10 ppm so that the cumulative exposure for the entire 8-hour work shift does not exceed a weighted average of 10 ppm.

(c) Table Z-3: an employee's exposure to any material listed in Table Z-3, in any 8-hour work shift of a 40-hour workweek, shall not exceed the 8-hour time-weighted average limit given for that material in the table.

(d) Computation formulae:

(1) (i) The cumulative exposure for an 8-hour work shift shall be computed as follows:

$$E = \frac{C_aT_a + C_b T_b + \dots C_n T_n}{8}$$

Where:

E is the equivalent cumulative exposure for the work shift.
C is the concentration during any period of time T where the concentration remains constant.
T is the duration in hours of the exposure at the concentration C.

The value of E shall not exceed the 8-hour time-weighted average limit in Tables Z-1, Z-2, or Z-3 for the material involved.

TABLE B-2 (continued)

(ii) To illustrate the formula prescribed in subdivision (i) of this subparagraph, note that isoamyl acetate has an 8-hour time-weighted average limit of 100 ppm (Table Z-1). Assume that an employee is subject to the following exposure:

Two hours' exposure at 150 ppm
Two hours' exposure at 75 ppm
Four hours' exposure at 50 ppm.

Substituting this information in the formula, we have

$$\frac{2 \times 150 + 2 \times 75 + 4 \times 50}{8} = 81.25 \text{ ppm}$$

Since 81.25 ppm is less than 100 ppm, the 8-hour time-weighted average limit, the exposure is acceptable.

(2) (i) In case of a mixture of air contaminants an employer shall compute the equivalent exposure as follows:

$$E_m = \frac{C_1}{L_1} + \frac{C_2}{L_2} + \ldots \frac{C_n}{L_n}$$

Where:
E_m is the equivalent exposure for the mixture.
C is the concentration of a particular contaminant.
L is the exposure limit for that contaminant, from Table Z-1, Z-2, or Z-3.

The value of E_m shall not exceed unity (1).

(ii) To illustrate the formula prescribed in subdivision (i) of this subparagraph, consider the following exposures:

Material	Actual concentration of 8-hour exposure	8-hour time-weighted average exposure limit
Acetone (Table Z-1)	500 ppm	1,000 ppm
2-Butanone (Table Z-1)	45 ppm	200 ppm
Toluene (Table Z-2)	40 ppm	200 ppm

Substituting in the formula, we have:

$$E_m = \frac{500}{1000} + \frac{45}{200} + \frac{40}{200}$$

$$E_m = 0.500 + 0.225 + 0.200$$

$$E_m = 0.925$$

Since E_m is less than unity (1), the exposure combination is within acceptable limits.

(e) To achieve compliance with paragraphs (a) through (d) of this section, administrative or engineering controls must first be determined and implemented whenever feasible. When such controls are not feasible to achieve full compliance, protective equipment or any other protective measures shall be used to keep the exposures of employees to air contaminants within the limits prescribed in this section. Any equipment and/or technical measures used for this

TABLE B-2 (continued)

purpose must be approved for by each particular use by a competent industrial hygienist or other technically qualified person. Whenever respirators are used, their use shall comply with CFR 29, Chapter XV, II Part 1910.134.

TABLE Z-1

Substance	ppm^{a}	mg/m^{3b}
Acetaldehyde	200	360
Acetic acid	10	25
Acetic anhydride	5	20
Acetone	1,000	2,400
Acetonitrile	40	70
Acetylene dichloride, see 1,2-Dichloroethylene		
Acetylene tetrabromide	1	14
Acrolein	0.1	0.25
Acrylamide-skin		0.3
Aldrin-skin		0.25
Allyl alcohol-skin	2	5
Allyl chloride	1	3
C Allylglycidyl ether (AGE)	10	45
Allyl propyl disulfide	2	12
2–Aminoethanol, see Ethanolamine		
2–Aminopyridine	0.5	2
Ammonia	50	35
Ammonium sulfamate (Ammate)		15
n–Amyl acetate	100	525
sec-Amyl acetate	125	650
Aniline-skin	5	19
Anisidine (o, *p*–isomers)–skin		0.5
Antimony and compounds (as Sb)		0.5
ANTU (Alpha naphthyl thiourea)		0.3
Arsenic and compounds (as As)		0.5
Arsine	0.05	0.2
Azinphos-methyl–skin		0.2
Barium (soluble compounds)		0.5
p–Benzoquinone, see Quinone		
Benzoyl peroxide		5
Benzyl chloride	1	5
Biphenyl, see Diphenyl		
Biphenyl A, see Diglycidyl ether		
Boron oxide		15
C Boron trifluoride	1	3
Bromine	0.1	0.7
Bromoform–skin	0.5	5
Butadiene (1,3–butadiene)	1,000	2,200
Butanethiol, see Butyl mercaptan		
2–Butanone	200	590
2–Butoxy ethanol (Butyl cellosolve)–skin	50	240
Butyl acetate (n–butyl acetate)	150	710
sec–Butyl acetate	200	950
tert–Butyl acetate	200	950
Butyl alcohol	100	300
sec–Butyl alcohol	150	450
tert–Butyl alcohol	100	300
C Butylamine–skin	5	15
C tert–Butyl chromate as (CrO_2)–skin		0.1
n–Butyl glycidyl ether (BGE)	50	270
Butyl mercaptan	10	35

(see footnotes at end of table) (continued)

TABLE B-2 (continued)

Substance	ppm[a]	mg/m^3[b]
p-tert-Butyltoluene	10	60
Calcium oxide		5
Camphor		2
Carbaryl (Sevin®)		5
Carbon black		3.5
Carbon dioxide	5,000	9,000
Carbon monoxide	50	55
Chlordane–skin		0.5
Chlorinated camphene–skin		0.5
Chlorinated diphenyl oxide		0.5
C Chlorine	1	3
Chlorine dioxide	0.1	0.3
C Chlorine trifluoride	0.1	0.4
C Chloroacetaldehyde	1	3
α–Chloroacetophenone (phenacylchloride)	0.05	0.3
Chlorobenzene (monochlorobenzene)	75	350
o–Chlorobenzyliden malonitrile (OCBM)	0.05	0.4
Chlorobromomethane	200	1,050
2–Chloro–1,3–butadiene, see Chloroprene		
Chlorodiphenyl (42 percent Chlorine)–skin		1
Chlorodiphenyl (54 percent Chlorine)–skin		0.5
1–Chloro,2,3–epoxypropane, see Epichlorhydrin		
2–Chloroethanol, see Ethylene chlorohydrin		
Chloroethylene, see Vinyl chloride		
C Chloroform (trichloromethane)	50	240
1–Chloro–1–nitropropane	20	100
Chloropicrin	0.1	0.7
Chloroprene (2–Chloro–1,3–butadiene)–skin	25	90
Chromium, sol. chromic, chromous salts as Cr		0.5
Metal and insol. salts		1
Coal tar pitch volatiles (benzene soluble fraction) anthracene, BaP, phenanthrene, acridine, chrysene, pyrene		0.2
Cobalt, metal fume and dust		0.1
Copper fume		0.1
Dusts and mists		1
Cotton dust (raw)		1
Crag® herbicide		15
Cresol (all isomers)–skin	5	22
Crotonaldehyde	2	6
Cumene–skin	50	245
Cyanide (as CN)–skin		5
Cyclohexane	300	1,050
Cyclohexanol	50	200
Cyclohexanone	50	200
Cyclohexene	300	1,015
Cyclopentadiene	75	200
2,4–D		10
DDT–skin		1
DDVP,		1
Decaborane–skin	0.05	0.3
Demeton® –skin	0.05	0.3
Diacetone alcohol (4–Hydroxymethyl 1–1–2–pentanone)	50	240

(see footnotes at end of table)

(continued)

TABLE B-2 (continued)

Substance	ppm[a]	mg/m^3[b]
1,2-Diaminoethane, see Ethylenediamine		
Diazomethane	0.2	0.4
Diborane	1	5
Dibutylphthalate		5
C *o*-Dichlorobenzene	50	300
p-Dichlorobenzene	75	450
Dichlorodifluoromethane	1,000	4,950
1,3-Dichloro-5.5-dimethyl hydantoin		0.2
1,1-Dichloroethane	100	400
1,2-Dichloroethylene	200	790
C Dichloroethyl ether-skin	15	90
Dichloromethane, see Methylene chloride (table Z-2)		
Dichloromonofluoromethane	1,000	4,200
C 1,1-Dichloro-1-nitroethane	10	60
1,2-Dichloropropane, see Proplyene dichloride		
Dichlorotetrafluoroethane	1,000	7,000
Dichlorvos (DDVP)-skin		1
Diedrin-skin		0.25
Diethylamine	25	75
Diethylamino ethanol-skin	10	50
Diethylether, see Ethyl ether		
Difluorodibromomethane	100	860
C Diglycidyl ether (DGE)	0.5	2.8
Dihydroxybenzene, see Hydroquinone		
Diisobutyl ketone	50	290
Diisopropylamine-skin	5	20
Dimethoxymethane, see Methylal		
Dimethyl acetamide-skin	10	35
Dimethylamine	10	18
Dimethylaminobenzene, see Xylidene		
Dimethylaniline (N-dimethylaniline)-skin	5	25
Dimethylbenzene, see Xylene		
Dimethyl 1,2-dibromo-2,2-dichlorethyl phosphate, (Dibrom)		3
Dimethylformamide-skin	10	30
2,6-Dimethylheptanone, see Disobutyl ketone		
1,1-Dimethylhydrazine-skin	0.5	1
Dimethylphthalate		5
Dimethylsulfate-skin	1	5
Dinitrobenzene (all isomers)-skin		1
Dinitro-*o*-cresol-skin		0.2
Dinitrotoluene-skin		1.5
Dioxane (Diethylene dioxide)-skin	100	360
Diphenyl	0.2	1
Diphenylmethane diisocyanate, see methylene bisphenyl isocyanate (MDI)		
Dipropylene glycol methyl ether-skin	100	600
Di-sec, octylphthalate (Di-2-ethylhexylphthalate		5
Endrin-skin		0.1
Epichlorohydrin-skin	5	19
EPN-skin		0.5
1,2-Epoxypropane, see Propylene oxide		
2,3-Epoxy-1-propanol, see Glycidol		
Ethanethiol, see Ethyl mercaptan		
Ethanolamine	3	6

(see footnotes at end of table) (continued)

TABLE B-2 (continued)

Substance	ppm[a]	mg/m3[b]
2-Ethoxyethanol-skin	200	740
2-Ethoxyethylacetate (Cellosolve-acetate)-skin	100	540
Ethyl acetate	400	1,400
Ethyl acrylate-skin	25	100
Ethyl alcohol (ethanol)	1,000	1,900
Ethylamine	10	18
Ethyl sec-amyl ketone (5-Methyl-3-heptanone)	25	130
Ethyl benzene	100	435
Ethyl bromide	200	890
Ethyl butyl ketone (3-Heptanone)	50	230
Ethyl chloride	1,000	2,600
Ethyl ether	400	1,200
Ethyl formate	100	300
C Ethyl mercaptan	10	25
Ethyl silicate	100	850
Ethylene chlorohydrin-skin	5	16
Ethylenediamine	10	25
Ethylene dibromide, see 1,2-Dibromoethane		
Ethylene dichloride, see 1,2-Dichloroethane		
C Ethylene glycol dinitrate and/or Nitroglycerin-skin	0.2[c]	1
Ethylene glycol monomethyl ether acetate, see Methyl cellosolve acetate		
Ethylene imine-skin	0.5	1
Ethylene oxide	50	90
Ethylidine chloride, see 1,1 Dichloroethane		
N-Ethylmorpholine-skin	20	94
Ferbam		15
Ferrovanadium dust		1
Fluoride (as F)		2.5
Fluorine	0.1	0.2
Fluorotrichloromethane	1,000	5,600
Formic acid	5	9
Furfural-skin	5	20
Furfural alcohol	50	200
Glycidol (2,3-Epoxy-1-propanol)	50	150
Glycol monoethyl ether, see 2-Ethoxyethanol		
Guthion®, see Azinphosmethyl		
Hafnium		0.5
Heptachlor-skin		0.5
Heptane (*n*-Heptane)	500	2,000
Hexachloroethane-skin	1	10
Hexachloronaphthalene-skin		0.2
Hexane (*n*-Hexane)	500	1,800
2-Hexanone	100	410
Hexone (Methyl isobutyl ketone)	100	410
sec-Hexyl acetate	50	300
Hydrazine-skin	1	1.3
Hydrogen bromide	3	10
C Hydrogen chloride	5	7
Hydrogen cyanide-skin	10	11
Hydrogen peroxide (90%)	1	1.4
Hydrogen selenide	0.05	0.2
Hydroquinone		2
C Iodine	0.1	1

(see footnotes at end of table)

(continued)

TABLE B-2 (continued)

Substance	ppm[a]	mg/m³[b]
Iron oxide fume		10
Isoamyl acetate	100	525
Isoamyl alcohol	100	360
Isobutyl acetate	150	700
Isobutyl alcohol	100	300
Isophorone	25	140
Isopropyl acetate	250	950
Isopropyl alcohol	400	980
Isopropylamine	5	12
Isopropylether	500	2,100
Isopropyl glycidyl ether (IGE)	50	240
Ketene	0.5	0.9
Lead arsenate		0.15
Lindane–skin		0.5
Lithium hydride		0.025
L.P.G. (liquified petroleum gas)	1,000	1,800
Magnesium oxide fume		15
Malathion–skin		15
Maleic anhydride	0.25	1
C Manganese		5
Mesityl oxide	25	100
Methanethiol, see Methyl mercaptan		
Methoxychlor		15
2-Methoxyethanol, see Methyl cellosolve		
Methyl acetate	200	610
Methyl acetylene (propyne)	1,000	1,650
Methyl acetylene–propadiene mixture (MAPP)	1,000	1,800
Methyl acrylate–skin	10	35
Methylal (dimethoxymethane)	1,000	3,100
Methyl alcohol (methanol)	200	260
Methylamine	10	12
Methyl amyl alcohol, see Methyl isobutyl carbinol		
Methyl (*n*-Amyl) ketone (2-Heptanone)	100	465
C Methyl bromide–skin	20	80
Methyl butyl ketone, see 2-Hexanone		
Methyl cellosolve–skin	25	80
Methyl cellosolve acetate–skin	25	120
Methyl chloroform	350	1,900
Methylcyclohexane	500	2,000
Methylcyclohexanol	100	470
o-Methylcyclohexanone–skin	100	460
Methyl ethyl ketone (MEK), see 2-Butanone		
Methyl formate	100	250
Methyl iodide–skin	5	28
Methyl isobutyl carbinol–skin	25	100
Methyl isobutyl ketone, see Hexone		
Methyl isocyanate–skin	0.02	0.05
C Methyl mercaptan	10	20
Methyl merthacrylate	100	410
Methyl propyl ketone, see 2-Pentanone		
C α Methyl styrene	100	480
C Methylene bisphenyl isocyanate (MDI)	0.02	0.2
Molybdenum:		
Soluble compounds		5
Insoluble compounds		15
Monomethyl aniline–skin	2	9

(see footnotes at end of table)

(continued)

TABLE B-2 (continued)

Substance	ppm[a]	mg/m^3[b]
C Monomethyl hydrazine–skin	0.2	0.35
Morpholine–skin	20	70
Naphtha (coal tar)	100	400
Naphthalene	10	50
Nickel carbonyl	0.001	0.007
Nickel, metal and soluble compounds, as Ni		1
Nicotine–skin		0.5
Nitric acid	2	5
Nitric oxide	25	30
p–Nitroaniline–skin	1	6
Nitrobenzene–skin	1	5
p–Nitrochlorobenzene–skin		1
Nitroethane	100	310
Nitrogen dioxide	5	9
Nitrogen trifluoride	10	29
Nitroglycerin–skin	0.2	2
Nitromethane	100	250
1–Nitropropane	25	90
2–Nitropropane	25	90
Nitrotoluene–skin	5	30
Nitrotrichloromethane, see Chloropicrin		
Octachloronaphthalene–skin		0.1
Octane	500	2,350
Oil mist, mineral		5[d]
Osmium tetroxide		0.002
Oxalic acid		1
Oxygen difluoride	0.05	0.1
Ozone	0.1	0.2
Paraquat–skin		0.5
Parathion–skin		0.1
Pentaborane	0.005	0.01
Pentachloronaphthalene–skin		0.5
Pentachlorophenol–skin		0.5
Pentane	1,000	2,950
2–Pentanone	200	700
Perchloromethyl mercaptan	0.1	0.8
Perchloryl fluoride	3	13.5
Petroleum distillates (naphtha)	500	2,000
Phenol–skin	5	19
p–Phenylene diamine–skin		0.1
Phenyl ether (vapor)	1	7
Phenyl ether–biphenyl mixture (vapor)	1	7
Phenylethylene, see Styrene (table Z–2)		
Phenylglycidyl ether (PGE)	10	60
Phenylhydrazine–skin	5	22
Phosdrin (Mevinphos®)–skin		0.1
Phosgene (carbonyl chloride)	0.1	0.4
Phosphine	0.3	0.4
Phosphoric acid		1
Phosphorus (yellow)		0.1
Phosphorus pentachloride		1
Phosphorus pentasulfide		1
Phosphorus trichloride	0.5	3
Phthalic anhydride	2	12
Picric acid–skin		0.1
Pival® (2–Pivalyl–1,3–indandione)		0.1
Platinum (soluble salts) as Pt		0.002

(see footnotes at end of table)

(continued)

TABLE B-2 (continued)

Substance	ppm[a]	mg/m³[b]
Propane	1,000	1,800
n-Propyl acetate	200	840
Propyl alcohol	200	500
n-Propyl nitrate	25	110
Propylene dichloride	75	350
Propylene imine-skin	2	5
Propylene oxide	100	240
Propyne, see Methyl acetylene		
Pyrethrum		5
Pyridine	5	15
Quinone	0.1	0.4
RDX-skin		1.5
Rhodium, metal fume and dusts, as Rh-		0.1
soluble salts		0.001
Ronnel		15
Rotenone (commercial)		5
Selenium compounds (as Se)		0.2
Selenium hexafluoride	0.05	0.4
Silver, metal and soluble compounds		0.01
Sodium fluoroacetate (1080)-skin		0.05
Sodium hydroxide		2
Stibine	0.1	0.5
Stoddard solvent	500	2,900
Strychnine		0.15
Sulfur dioxide	5	13
Sulfur hexafluoride	1,000	6,000
Sulfuric acid		1
Sulfur monochloride	1	6
Sulfur pentafluoride	0.025	0.25
Sulfuryl fluoride	5	20
Systox, see Demeton 2,4,5, T		10
Tantalum		5
TEDP-skin		0.2
Tellurium		0.1
Tellurium hexafluoride	0.02	0.2
TEPP-skin		0.05
C-Terphenyls	1	9
1,1,1,2-Tetrachloro-2,2-difluoroethane	500	4,170
1,1,2,2-Tetrachloro-1,2-difluoroethane	500	4,170
1,1,2,2-Tetrachloroethane-skin	5	35
Tetrachloroethylene, see Perchloroethylene		
Tetrachloromethane, see Carbon tetrachloride (table Z-2)		
Tetrachloronaphthalene-skin		2
Tetraethyl lead (as Pb)-skin		0.075[e]
Tetrahydrofuran	200	590
Tetramethyl lead (as Pb)-skin		0.075
Tetramethyl succinonitrile-skin	0.5	3
Tetranitromethane	1	8
Tetryl (2,4,6-trinitrophenyl-methylnitramine)-skin		1.5
Thallium (soluble compounds)-skin as T1		0.1
Thiram		5
Tin (inorganic compounds, except oxides)		2
Tin (organic compounds)		0.1
Titanium dioxide		15
C Toluene-2,4-diisocyanate	0.02	0.14
o-Toluidine-skin	5	22

(see footnotes at end of table)

(continued)

TABLE B-2 (continued

Substance	ppm[a]	mg/m3[b]
Toxaphene, see Chlorinated camphene		
Tributyl phosphate		5
1,1,1-Trichloroethane, see Methyl chloroform		
1,1,2-Trichloromethane-skin	10	45
Trichloromethane, see Chloroform		
Trichloronaphthalene-skin		5
1,2,3-Trichloropropane	50	300
1,1,2-Trichloro 1,2,2-trifluoroethane	1,000	7,600
Triethylamine	25	100
Trifluoromonobromomethane	1,000	6,100
2,4,6-Trinitrophenol, see Picric acid		
2,4,6-Trinitrophenylmethylnitramine, see Tetryl		
Trinitrotoluene-skin		1.5
Triorthocresyl phosphate		0.1
Triphenyl phosphate		3
Turpentine	100	560
Uranium (soluble compounds)		0.05
Uranium (insoluble compounds)		.25
C Vanadium:		
V_2O_5		0.5
V_2O_5 fume		0.1
Vinyl benzene, see Styrene (table Z-2)		
Vinylcyanide, see Acrylonitrile		
Vinyl toluene	100	480
Warfarin		0.1
Xylene (xylol)	100	435
Xylidine-skin	5	25
Yttrium		1
Zinc chloride fume		1
Zinc oxide fume		5
Zirconium compounds (as Zr)		5

[a] Parts of vapor or gas per million parts of contaminated air by volume at 25° C and 760 mm Hg pressure.

[b] Approximate milligrams of particulate per cubic meter of air.

[c] An atmospheric concentration of not more than 0.02 ppm or personal protection may be necessary to avoid headache.

[d] As sampled by method that does not collect vapor.

[e] For control of general room air, biologic monitoring is essential for personnel control.

TABLE Z-2

Material	8-hour time weighted average	Acceptable ceiling concentration	Acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift	
			Concentration	Maximum duration
Benzene (Z37.4-1969)	10 ppm	25 ppm	50 ppm	10 minutes
Beryllium and beryllium compounds (Z37.29-1970)	2 $\mu g/m^3$	5 $\mu g/m^3$	25 $\mu g/m^3$	30 minutes
Cadmium fume (Z37.5-1970)	0.1 mg/m^3	0.3 mg/m^3		
Cadmium dust (Z37.5-1970)	0.2 mg/m^3	0.6 mg/m^3		

(continued)

TABLE B-2 (continued)

TABLE Z-2 (con.)

Material	8-hour time weighted average	Acceptable ceiling concentration	Acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift	
			Concentration	Maximum duration
Carbon disulfide (Z37.3-1968)	20 ppm	30 ppm	100 ppm	30 min
Carbon tetrachloride (Z37.17-1967)	10 ppm	25 ppm	200 ppm	5 minutes in any 4 hours
Ethylene dibromide (Z37.31-1970)	20 ppm	30 ppm	50 ppm	5 minutes
Ethylene dichloride (Z37.21-1969)	50 ppm	100 ppm	200 ppm	5 minutes in any 3 hours
Formaldehyde (Z37.16-1967)	3 ppm	5 ppm	10 ppm	30 minutes
Hydrogen fluoride (Z37.28-1969)	3 ppm			
Fluoride as dust (Z37.28-1969)	2.5 mg/m^3			
Methyl chloride (Z37.18-1969)	100 ppm	200 ppm	300 ppm	5 minutes in any 3 hours
Methylene chloride (Z37.23-1969)	500 ppm	1,000 ppm	2,000 ppm	5 minutes in any 2 hours
Organo (alkyl) mercury (Z37.30-1969)	0.01 mg/m^3	0.04 mg/m^3		
Styrene (Z37.15-1969)	100 ppm	200 ppm	600 ppm	5 minutes in any 3 hours
Trichloroethylene (Z37.19-1967)	100 ppm	200 ppm	300 ppm	5 minutes in any 2 hours
Tetrachloroethylene (Z37.22-1967)	100 ppm	200 ppm	300 ppm	5 minutes in any 3 hours
Toluene (Z37.12-1967)	200 ppm	300 ppm	500 ppm	10 minutes
Hydrogen sulfide (Z37.2-1966)		20 ppm	50 ppm	10 minutes once only if no other measurable exposure occurs.
Mercury (Z37.8-1971)		1 mg/10 m^3		
Chromic acid and chromates (Z37.7-1971)		1 mg/10 m^3		

(ANSI document number)

TABLE Z-3

Substance	mppcf[a]	mg/m^3
Silica:		
Crystalline:		
Quartz (respirable)	$\frac{250^{b}}{\% \ SiO_2 + 5}$	$\frac{10 \ mg/m^{3c}}{\% \ SiO_2 + 2}$
Quartz (total dust)		$\frac{30 \ mg/m^3}{\% \ S_2O_2 + 2}$
Cristobalite: Use one-half the value calculated from the count or mass formulae for quartz.		
Tridymite: Use one-half the value calculated from the formulae for quartz.		

(see footnotes at end of table)

(continued)

TABLE B-2 (continued)

TABLE Z-3 (con.)

Substance	mppcf[a]	mg/m^3
Amorphous, including natural diatomaceous earth	20	$\frac{80\ mg/m^3}{\%\ SiO_2}$
Silicates (less than 1% crystalline silica):		
Mica	20	
Soapstone	20	
Talc (nonasbestos form)	20[d]	
Talc (fibrous). Use asbestos limit		
Tremolite (see talc, fibrous)		
Portland cement	50	
Graphite (natural)	15	
Coal dust (respirable fraction less than 5% SiO_2)		2.4 mg/m^3 or
For more than 5% SiO_2		$\frac{10\ mg/m^3}{\%\ SiO_2 + 2}$
Inert or nuisance dust:		
Respirable fraction	15	5 mg/m^3
Total dust	50	15 mg/m^3

[a] Millions of particles per cubic foot of air, based on impinger samples counted by light-field techniques.

[b] The percentage of crystalline silica in the formula is the amount determined from airborne samples, except in those instances in which other methods have been shown to be applicable.

[c] Both concentration and percent quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:

Aerodynamic diameter (unit density sphere)	Percent passing selector
2.0	90
2.5	75
3.5	60
5.0	25
10.0	0

The measurements under this note refer to the use of an AEC instrument. If the respirable fraction of coal dust is determined with an MRE, the figure corresponding to that of 2.4 mg/m^3 in the table for coal dust is 4.5 mg/m^3. [39 FR 23502, June 27, 1974. Redesignated and amended at 40 FR 23073, May 28, 1975.]

[d] Containing < 1% quartz; if > 1% quartz, use quartz limit.

TABLE B-3 OSHA SUBSTANCE SPECIFIC HEALTH STANDARDS ADOPTED AFTER 1972

Substance (CFR section)	Hazard	Work practices[a]	Permissible exposure limit (PEL)
2-Acetylamino fluorine (1014)	Potential carcinogen	X	
Acrylonitrile (1045)	Potential carcinogen	X	2 ppm TWA 10 ppm (15 min C)
4-Aminodiphenyl (1011)	Potential carcinogen	X	
Arsenic (Inorg.)	Potential carcinogen	X	10 μg/m^3 TWA 2 fibers longer than 5 μm/cc
Asbestos (1001)	Potential carcinogen	X	C 10 fibers longer than 5 μm/cc
Benzene (1028)	Potential carcinogen	X	1 ppm 5 ppm C } revoked by court action
Benzidine (1010)	Potential carcinogen	X	
bis-Chloromethyl ether (1008)	Potential carcinogen	X	
Coal tar pitch volatiles (1002)	Potential carcinogens	X	
Coke oven emissions (1029)	Potential carcinogens	X	150 μg/m^3 TWA
Cotton dust (1043)	Respiratory hazard	X	200 μg/m^3 textile yarn 750 μg/m^3 slashing and weaving 500 μg/m^3 other operations
1,2-Dibromo-3-chloropropane DBCP (1044)	Potential carcinogen	X	1 ppb TWA No eye or skin contact
3,3′-Dichlorobenzidine (and salts) (1007)	Potential carcinogen	X	
4-Dimethylamino-azobenzene (1015)	Potential carcinogen	X	
Ethyleneamine (1012)	Potential carcinogen	X	
Lead (1025)	Neurotoxicity	X	50 μg/m^3 TWA
Methyl chloromethyl ether (1006)	Potential carcinogen	X	
4,4′-Methylene-*bis* (2-chloroaniline) (1005)	(Standard set aside by court action)		
α-Naphthylamine (1006)	Potential carcinogen	X	
β-Naphthylamine (1009)	Potential carcinogen	X	
4-Nitrobiphenyl (1003)	Potential carcinogen	X	
N-Nitrosodimethylamine (1016)	Potential carcinogen	X	
β-Propiolactone	Potential carcinogen	X	
Vinyl chloride	Potential carcinogen	X	1 ppm TWA 5 ppm (15 min C)

[a] Work practices include personal protective equipment, respirators, environmental monitoring, medical surveillance, labeling, record-keeping, housekeeping, waste disposal and employee information and training.

TABLE B-4 SUMMARY OF NIOSH RECOMMENDATIONS

Substances	**Date to OSHA**	**Recommended level**[a]
Acetylene	July 1976	2,500 ppm
Acrylamide	October 1976	0.3 mg/m^3 10 hr TWA
Acrylonitrile	September 1977	2 ppm
Aldrin/dieldrin	September 1978	0.25 mg/m^2
Alkanes (C^5–C^8)	March 1977	350 mg/m^3
Allyl chloride	September 1976	1,800 mg/m^3 15 min C 1 ppm TWA 3 ppm (15 min Ceil)
Allylglycidylether	July 1978	45 mg/m^{3}15 min Ceil
Ammonia	July 1974	50 ppm 5 min Ceil
Antimony	September 1978	0.5 mg/m^3
Arsenic, inorganic	June 1975	2 μg ppm/m^3 15 min C
Asbestos	December 1976	100,000 fibers/m^3 over 5μm TWA, 500,000 fibers/m^3 over 5 μm C
Asphalt fumes	September 1977	5 mg/m^3 15 min C
Benzene	July 1977	1 ppm 5 ppm Ceil
Benzoyl peroxide	June 1977	5 mg/m^3 10 hr-TWA
Benzyl chloride	August 1978	1 ppm (5 mg/m^2)
Beryllium	August 1977	0.5 μg/m^3 TWA 30 min Ceil
Boron trifluoride	December 1976	No recommendation
Cadmium (dust & fume)	August 1976	40 μg/m^3 TWA 200 μg/m^3 C
Carbaryl (Sevin®)	September 1976	5 mg/m^3 (10 hr TWA)
Carbon black	September 1978	3.5 mg/m^3 30,000 ppm 10 min C
Carbon dioxide	August 1976	10,000 ppm/10 hr TWA
Carbon disulfide	May 1977	1 ppm, 10 ppm Ceil
Carbon monoxide	August 1972	35 ppm 10 hr TWA 200 ppm C
Carbon tetrachloride	June 1976	2 ppm/1 hr Ceil
Chlorine	May 1976	0.5 ppm 15 min Ceil
Chloroform	June 1976	2 ppm/1 hr Ceil
Chloroprene	August 1977	1 ppm (15 min Ceil)
Chromic acid	July 1973	0.05 mg/m^3 TWA 15 min C 0.1 mg/m^3
Chromium (VI)	December 1975	1 mg/m^3
Chrysene	June 1978	0.1 mg/m^3 10 hr TWA
Coal tar pitch volatiles	September 1977	
Coke oven emissions	February 1973	Work practices
Cotton dust	September 1974	0.2 mg/m^3 (lint-free cotton dust)
Cresol	February 1978	5 ppm (22 mg/m^3)
Cyanide, hydrogen and cyanide salts	October 1976	5 mg/m^3 (10 min Ceil)
DDT	September1978	1 mg/m^3
Decomposition products of fluorocarbon	September 1977	No recommendation
Dibromochloropropane	September 1977	10 ppb 30 min C
Diisocyanatos	September 1978	40 μg/m^3
Dinitro-ortho-cresol	February 1978	0.2 mg/m^3
Dioxane	September 1977	1 ppm/30 min C

(continued)

TABLE B-4 (continued)

Substances	Date to OSHA	Recommended level[a]
Epichlorohydrin	September 1976	2 mg/m^3 19 mg/m^3 15 min Ceil
Ethylene dibromide	August 1977	1 mg/m^3 15 min Ceil
Ethylene dichloride	September 1978	5 ppm 15 ppm 15 min Ceil
Ethylene oxide	September 1977	75 ppm 15 min Ceil
Ethylene thiourea	October 1978	3,000,000 fibers/m^3 TWA
Fibrous glass	April 1977	5 mg/m^3 TWA
Fluorides, inorganic	June 1975	2.5 mg/m^3
Formaldehyde	December 1976	1.2 mg/m^3 30 min Ceil
Furfural alcohol	March 1979	6.0 mg/m^3 TWA
Glycidyl ethers	June 1978	240 mg/m^3 Ceil 15 min
Hot environments	June 1972	variable
Hydrazines	June 1978	1 ppm (1.3 mg/m^3)
Phenylhydrazine		.6 mg/m^3 15 min C
Hydrogen fluoride	March 1976	2.5 mg/m^3 5 mg/m^3
Hydrogen sulfide	May 1977	15 min C 10 min 15 mg/m^3 C
Hydroquinone	April 1978	2 mg/m^3 800 ppm/ 15 min Ceil
Isopropyl alcohol	March 1976	400 ppm 10 hr TWA 800 ppm 15 min C
Kepone	January 1976	1 μg/m^3 15 min Ceil
Ketones (acetone)	June 1978	590 mg/m^3 TWA
Lead, inorganic	March 1977	< 100 μg/m^3
Malathion	July 1976	15 mg/m^3 10 hr TWA
Mercury, inorganic	January 1973	0.05 mg/m^3
Methyl alcohol	March 1976	200 ppm 800 ppm 15 min C
4,4'-Methylene-bis (2-chloroaniline)	September 1978	
Methyl parathion	September 1976	0.2 mg/m^3 TWA 10 hr TWA
Methylene chloride	March 1976	75 ppm 500 ppm 15 min Ceil
Nickel carbonyl	May 1977	0.001 ppm
Nickel, inorganic and compounds	May 1977	0.015 mg/m^3 10 hr TWA
Nitric acid	March 1976	2 ppm 10 hr TWA
Nitriles	September 1978	
Nitrogen oxides, NO	March 1976	25 ppm 1 ppm Ceil (1.8 mg/m^3)
Nitrogylcerine	June 1978	1 mg/m^3 Ceil
Noise	August 1972	85 dBA TWA 115 dBA Ceil
Organotin compounds	November 1976	0.1 mg/m^3
Parathion	June 1976	0.05 mg/m^3 10 hr TWA
Phenol	June 1976	20 mg/m^3 60 mg/m^3 15 min Ceil 0.1 ppm 10 hr TWA
Phosgene	February 1976	0.2 ppm 15 min Ceil
Polychlorinated biphenyls	September 1977	1.0 μg/m^3 TWA
Refined petroleum solvent	July 1977	350 mg/m^3 15 min C

(continued)

TABLE B-4 (continued)

Substances	**Date to OSHA**	**Recommended level**[a]
Silica, crystalline	November 1974	50 $\mu g/m^3$ 10 hr TWA
Sodium hydroxide	September 1975	2 mg/m^3 15 min Ceil
Sulfur dioxide	May 1977	0.5 ppm
Sulfric acid	June 1974	1 mg/m^3 10 hr TWA
1,1,2,2-Tetrachloroethane	December 1976	1 ppm 10 hr TWA
Tetrachloroethylene	July 1976	50 ppm TWA 100 pm Ceil
Thiols	September 1978	
N-Alkane mono		
Cyclohexane		2.4 mg/m^3 C
Benzene		.5 mg/m^3 C
o-Tolidine	August 1978	20 $\mu g/m^3$ 5 ppm (22 mg/m^3)
Toluene	July 1973	100 ppm 200 ppm 10 min Ceil
Toluene diisocyanate	September 1978	0.005 ppm TWA 0.02 ppm 20 min Ceil
1,1,1-Trichloroethane	July 1976	350 ppm TWA
Trichloroethylene	February 1978	100 ppm 150 ppm 15 min Ceil
Tungsten	September 1977	5 mg/m^3 TWA
Tungsten carbide cemented		
Ultraviolet radiation	December 1972	1.0 mW/cm^2 for over 1,000 s 100 mW sec/cm for under 1,000 s
Vanadium	August 1977	0.05 mg/m^3 15 min Ceil
Vinyl acetate	September 1978	15 mg/m^3 C
Vinyl chloride	March 1974	Lowest feasible level
Vinyl halides	September 1978	1 ppm Ceiling 15 min
Waste anesthetic gases and vapors	March 1977	1 ppm C 2 ppm C (1 hr) 25 ppm TWA during use
Xylene	May 1975	200 ppm/10 min Ceil 100 ppm 10 hr TWA 15 min Ceil
Zinc oxide	October 1975	5 mg/m^3 TWA 15 mg/m^3 15 mg/m^3 15 min C

[a] The level indicated is the recommended time-weighted average (TWA) based on a 10-hour day or 40-hour week unless stated as a ceiling (C) value. In addition to the quantitative recommendations work practices to minimize exposure are described in the individual criteria documents

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]

Compound	TWA ppm	TWA mg/cu m	Comment	OSHA Value Comparison[c]
Acetaldehyde	100	180		L
Acetic acid	10	25		S
Acetic anhydride	5	20	Ceiling	S
Acetone	750	17800		L
Acetonitrile	40	70	Skin	S
Acetylene tetrabromide	1	15		S
Acetylsalicyclic acid	-	5		
Acrolein	0.1	0.25		S
Acrylamide	-	0.3	Skin	S
Acrylic acid	10	30		
Acrylonitrile	2	4.5	Human carcinogen	
Proposed	2	4.5	Suspect carcinogen	
Aldrin	-	0.25	Skin	S
Allyl alcohol	2	5	Skin	S
Allyl chloride	1	3		S
Allyl glycidyl ether	5	22	Skin	L
Allyl propyl disulfide	2	12		S
Alpha alumina	-	10	Nuisance particulate	
Aluminum				
Metal & oxide	-	10		
Pyro powders	-	5		
Soluble salts	-	5		
Alkyls (NOC)	-	2		
4-Aminodiphenyl	-	-	Skin; Human carcinogen	
2-Aminopyridine	0.5	2		S
Amitrol	-	-	Suspect carcinogen	
Ammonia	25	18		L
Ammonium sulfamate	-	10		L
n-Amyl acetate	100	530		S
sec-Amyl acetate	125	670		
Aniline & homologs	2	10	Skin	L
Anisidine (o-,p- isomers)	0.1	0.5	Skin	S
Antimony & compounds	-	0.5		S
Antimony trioxide (handling and use)	-	0.5		
ANTU (alpha naphthyl thiourea)	-	0.3		S
Arsenic (Soluble (compounds, As)	-	0.2		L
Arsine	0.05	0.2		S
Atrazine	-	5		

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S^{a,b}
(Continued)

Compound	TWA ppm	TWA mg/cu m	Comment	OSHA Value Comparison^{c}
Azinphos-methyl	-	0.2	Skin	S
Barium (soluble compounds, as Ba)	-	0.5		S
Benomyl	0.8	10		
Benzene	10	30	Suspect carcinogen	
Benzidine	-	-	Skin; Human carcinogen	
Benzoyl peroxide	-	5		S
Benzo(a)pyrene	-	-	Suspect carcinogen	
Benzyl chloride	1	5		S
Beryllium	-	0.002	Suspect carcinogen	
Biphenyl	0.2	1.5		S
Borates, tetra sodium salts				
Anhydrous	-	1		
Decahydrate	-	5		
Pentahydrate	-	1		
Boron oxide	-	10		L
Boron tribromide	1	10		
Boron trifluoride	1	3	Ceiling	S
Bromacil	1	10		
Bromine	0.1	0.7		S
Bromine pentafluoride	0.1	0.7		
Bromoform	0.5	5	Skin	S
1,3,-Butadiene	1000	2200		S
Proposed	-	-	Suspect carcinogen	L
Butane	800	1900		
2-Butoxyethanol	25	120	Skin	L
n-Butyl acetate	150	710		S
sec-Butyl acetate	200	950		S
tert-Butyl acetate	200	950		S
Butyl acrylate	10	55		
n-Butyl alcohol	50	150	Ceiling	L
sec-Butyl alcohol	100	305		L
tert-Butyl alcohol	100	300		S
Butylamine	5	15	Skin; Ceiling	S
tert-Butyl chromate	-	0.1	Skin; Ceiling	S
n-Butyl glycidal ether	25	135		L
n-Butyl lactate	5	25		
Butyl mercaptan	0.5	1.5		L
o-sec-Butylphenol	5	30	Skin	
p-tert-Butyltoluene	10	60		S

(Continued)

TABLE B-5, 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]
(Continued)

Compound	TWA ppm	TWA mg/cu m	Comment	OSHA Value Comparison[c]
Cadium dust & salts, as Cd	-	0.05		
Calcium carbonate/marble	-	10	Nuisance particulate	
Calcium cyanamide	-	0.5		
Calcium hydroxide	-	5		
Calcium oxide	-	2		L
Calcium silicate	-	10	Nuisance particulate	
Camphor, synthetic	2	12		H
Caprolactam				
Dust	-	1		
Vapor	5	20		
Captafol	-	0.1	Skin	
Captan	-	5		
Carbaryl	-	5		S
Carbofuran	-	0.1		
Carbon black	-	3.5		S
Carbon disulfide	10	30	Skin	
Carbon monoxide	50	55		S
Carbon tetrabromide	0.1	1.4		
Carbon tetrachloride	5	30	Skin; Suspect carcinogen	
Carbonyl fluoride	2	5		
Catechol	5	20		
Cellulose (paper fiber)	-	10	Nuisance particulate	
Cesium hydroxide	-	2		
Chlordane	-	0.5	Skin	S
Chlorinated camphene	-	0.5	Skin	S
Chlorinated diphenyl oxide	-	0.5		S
Chlorine	1	3		S
Chlorine dioxide	0.1	0.3		S
Chlorine trifluoride	0.1	0.4	Ceiling	S
Chloroacetaldehyde	1	3	Ceiling	S
alpha-Chloroacetophenone	0.05	0.3		S
Chloroacetyl chloride	0.05	0.2		
Chlorobenzene	75	350		S
o-Chlorobenzylidene malonitrile	0.05	0.4	Skin; Ceiling	S
Chlorobromomethane	200	1050		S
Chlorodifluoromethane	1000	3500		
Chlorodiphenyl (42% chlorine)	-	1	Skin	S

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]
(Continued)

Compound	TWA		Comment	OSHA Value Comparison[c]
	ppm	mg/cu m		
Chlorodiphenyl (54% chlorine)	-	0.5	Skin	S
Chloroform	10	50	Suspect carcinogen	L
bis-Chloromethyl ether	0.001	0.005	Human carcinogen	
Chloromethyl methyl ether	-	-	Suspect carcinogen	
1-Chloro-1-nitropropane	2	10		L
Chloropentafluoroethane	1000	6320		
Chloropicrin	0.1	0.7		S
beta-Chloroprene	10	45	Skin	L
o-Chlorostyrene	50	285		
o-Chlorotoluene	50	250	Skin	
Chloropyrifos	-	0.2	Skin	
Chromium metal	-	0.5		L
Chromium (II) compounds, as Cr	-	0.5		S
Chromium (III) compounds, as Cr	-	0.5		S
Chromium (VI) compounds,				
Water soluble, as Cr	-	0.05		
Certain water insoluble	-	0.05	Human carcinogen	L
Chromyl chloride	0.025	0.15		
Chrysene	-	-	Suspect carcinogen	
Clopidol	-	10		
Coal tar pitch volatiles (as benzene solubles)	-	0.2	Human carcinogen	S
Cobalt metal, dust & fume, as Co		0.1		S
Proposed	-	0.05		L
Cobalt carbonyl, as Co	-	0.1		
Cobalt hydrocarbonyl, as Co	-	0.1		
Copper				
Fume	-	0.2		H
Dusts & mists, as Cu	-	1		S
Cresol (all isomers)	5	22	Skin	S
Crotonaldehyde	2	6		S
Crufomate	-	5		
Cumene	50	245	Skin	S
Cyanamide	-	22		
Cyanides, as CN	-	5	Skin	S
Cyanogen	10	20		

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]
(Continued)

	TWA		Comment	OSHA Value
Compound	ppm	mg/cu m		Comparison[c]
Cyanogen chloride	0.3	0.6	Ceiling	
Cyclohexane	300	1050		S
Cyclohexanol	50	200		S
Cyclohexanone	25	100		L
Cyclohexene	300	1015		S
Cyclohexylamine	10	40	Skin	
Cyclonite	-	1.5		
Cyclopentadiene	75	200		S
Cyclopentane	600	1720		
Cyhexatin	-	5		
2,4-D	-	10		S
DDT	-	1		S
Decaborane	0.05	0.3	Skin	S
Demeton	0.01	0.1	Skin	L
Diacetone alcohol	50	240		S
Diazinon	-	0.1	Skin	
Diazomethane	0.2	0.4		
Diborane	0.1	0.1		S
2-N-Dibutylaminoethanol	2	14	Skin	L
Dibutyl phosphate	1	5		
Dibutyl phthalate	-	5		S
Dichloroacetylene	0.1	0.4	Ceiling	
o-Dichlorobenzene	50	300	Ceiling	S
p-Dichlorobenzene	75	450		S
3,3'-Dichlorobenzidine	-	-	Skin; Suspect carcinogen	
Dichlorodifluoromethane	1000	4950		S
1,3-Dichloro-5,5-dimethyl hydantoin	-	0.2		S
1,1-Dichloroethane	200	810		H
1,2-Dichloroethylene	200	790		S
Dichloroethyl ether	5	30	Skin	L
Dichlorofluoromethane	10	40		L
1,1-Dichloro-1-nitro-ethane	2	10		L
Dichloropropene	1	5	Skin	
2,2-Dichloropropionic acid	1	6		
Dichlorotetrafluoroethane	1000	7000		S
Dichlorvos	0.1	1	Skin	H
Dicrotophos	-	0.25	Skin	
Dicyclopentadiene	5	30		

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S^{a,b} (Continued)

Compound	TWA ppm	TWA mg/cu m	Comment	OSHA Value Comparison^{c}
Dicyclopentadienyl iron	-	10		
Dieldrin	-	0.25	Skin	S
Diethanolamine	3	15		
Diethylamine	10	30		L
Diethylaminoethanol	10	50	Skin	S
Diethylene triamine	1	4	Skin	
Diethyl ketone	200	705		
Diethyl phthalate	-	5		
Difluorodibromomethane	100	860		S
Diglycidyl ether	0.1	0.5		L
Diisobutyl ketone	25	150		L
Diisopropylamine	5	20	Skin	S
Dimethyl acetamide	10	35	Skin	S
Dimethylamine	10	18		S
Dimethylaniline	5	25	Skin	S
Dimethyl carbamyl chloride	-	-	Suspect carcinogen	
Dimethylformamide	10	30	Skin	S
1,1-Dimethylhydrazine	0.5	1	Skin; Suspect carcinogen	S
Dimethylphthalate	-	5		S
Dimethyl sulfate	0.1	0.5	Skin; Suspect carcinogen	L
Dinitolmide	-	5		
Dinitrobenzene (all isomers)	0.15	1	Skin	S
Dinitro-o-cresol	-	0.2	Skin	S
Dinitrotoluene	-	1.5	Skin	S
Dioxane (tech. grade)	25	90	Skin	L
Dioxathion	-	0.2	Skin	
Diphenylamine	-	10		
Dipropylene glycol methyl ether	100	600		S
Dipropyl ketone	50	235		
Diquat	-	0.5		
Di-sec-octyl phthalate	-	5		S
Disulfiram	-	2		
Disulfaton	-	0.1		
2,6-Ditert-butyl-p-cresol	-	10		
Diuron	-	10		
Divinyl benzene	10	50		
Emery	-	10	Nuisance particulate	
Endosulfan	-	0.1	Skin	

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]
(Continued)

Compound	TWA ppm	 mg/cu m	Comment	OSHA Value Comparison[c]
Endrin	-	0.1	Skin	S
Enflurane (Proposed)	75	575		
Epichlorohydrin	2	10	Skin	L
EPN	-	0.5	Skin	S
Ethanolamine	3	8		S
Ethion	-	0.4	Skin	
2-Ethoxyethanol	50	185	Skin	L
Proposed	5	19	Skin	L
2-Ethoxyethyl acetate	50	270	Skin	L
Proposed	5	27	Skin	L
Ethyl acetate	400	1400		S
Ethyl acrylate	2	20	Skin	L
Ethyl alcohol	1000	1900		S
Ethylamine	10	18		S
Ethyl amyl ketone	25	130		S
Ethyl benzene	100	435		S
Ethyl bromide	200	890		S
Ethyl butyl ketone	50	230		S
Ethyl chloride	1000	2600		S
Ethylene chlorohydrin	1	3	Skin; Ceiling	L
Ethylenediamine	10	25		S
Ethylene dibromide	-	-	Human carcinogen; Skin	
Ethylene dichloride	10	40		
Ethylene glycol	-	-		
Particulate	-	10		
Proposed	-	-		
Vapor	50	125	Ceiling	
Ethylene glycol dinitrate				
Proposed	0.05	0.3	Skin	L
Ethylene oxide	10	20		L
Proposed	1	2	Suspect carcinpgen	L
Ethyleneimine	0.5	1	Skin	S
Ethyl ether	400	1200		S
Ethyl formate	100	300		S
Ethylidene norborene	5	25	Ceiling	
Ethyl mercaptan	0.5	1		L
N-Ethylmorphine	5	23	Skin	L
Ethyl silicate	10	85		L
Fenamiphos (Proposed)	-	0.1	Skin	
Fensulfothion	-	0.1		
Fenthion	-	0.2	Skin	

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S^{a,b}
(Continued)

Compound	TWA ppm	TWA mg/cu m	Comment	OSHA Value Comparison^{c}
Ferbam	-	10		L
Ferrovanadium dust	-	1		S
Fibrous glass dust	-	10		
Fluorides, as F	-	2.5		S
Fluorine	1	2		H
Fonofos	-	0.1	Skin	
Formaldehyde	2	3	Ceiling	
Proposed	1	1.5	Suspect carcinogen	
Formamide	20	30		
Formic acid	5	9		S
Furfural	2	8	Skin	L
Furfuryl alcohol	10	40	Skin	L
Gasoline	300	900		
Germanium tetrahydride	0.2	0.6		
Glutaraldehyde	0.2	0.7		
Glycidol	25	75		L
Grain dust (Proposed)	-	4		
Graphite (synthetic)	-	10	Nuisance particulate	
Gypsum	-	10	Nuisance particulate	
Hafnium	-	0.5		S
Halothane (Proposed)	50	400		
Heptachlor	-	0.5	Skin	S
Heptane	400	1600		L
Hexachlorobutadiene	0.02	0.24	Suspect carcinogen	
Hexachlorocyclopentadiene	0.01	0.1		
Hexachloroethane	10	100		H
Hexachloronaphthalene	-	0.2		S
Hexafluoroacetone	0.1	0.7		
Hexamethyl phosphoramide	-	-	Skin;Suspect carcinogen	
Hexane				
N-Hexane	50	180		L
Other isomers	500	1800		
sec-Hexyl acetate	50	300		S
Hexylene glycol	25	125	Ceiling	
Hydrazine	0.1	0.1	Skin;Suspect carcinogen	L
Hydrogenated terphenyls	0.5	5		
Hydrogen bromide	3	10		S
Hydrogen chloride	5	7	Ceiling	S
Hydrogen cyanide	10	10	Skin; Ceiling	S
Hydrogen fluoride, as F	3	2.5		
Hydrogen peroxide	1	1.5		S

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]
(Continued)

Compound	TWA ppm	 mg/cu m	Comment	OSHA Value Comparison[c]
Hydrogen selenide	0.05	0.2		S
Hydrogen sulfide	10	14		
Hydroquinone	-	2		S
2-Hydroxypropyl acrylate	0.5	3	Skin	
Indene	10	45		
Indium & compounds, as In	-	0.1		
Iodine	0.1	1	Ceiling	S
Iodoform	0.6	10		
Iron pentacarbonyl, as Fe	0.1	0.8		
Iron salts, soluble, as Fe	-	1		
Isoamyl acetate	100	525		S
Isoamyl alcohol	100	360		S
Isobutyl acetate	150	700		S
Isobutyl alcohol	50	150		L
Isooctyl alcohol	50	270		
Isophorone	5	25	Ceiling	L
Isophorone diisocyanate	0.01	0.09	Skin	
Isopropoxyethanol	25	105		
Isopropyl acetate	250	950		S
Isopropyl alcohol	400	980		S
Isopropylamine	5	12		S
N-Isopropylaniline	2	10	Skin	
Isopropyl ether	250	1050		L
Isopropyl glycidyl ether	50	240		S
Kaolin	-	10	Nuisance particulate	
Ketene	0.5	0.9		S
Lead, inorganic dusts & fume, as Pb	- -	- 0.15		
Lead arsenate, as Pb3(AsO4)2 (Proposed)	-	0.15		S
Lead chromate, as Cr	-	0.05		
Limestone	-	10	Nuisance particulate	
Lindane	-	0.5	Skin	S
Lithium hydride	-	0.025		S
L.P.G. (Liquifid petroleum gas)	1000	1800		S
Magnesite	-	10	Nuisance particulate	
Malathion	-	10	Skin	L
Maleic anhydride	0.25	1		S

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]
(Continued)

Compound	TWA ppm	TWA mg/cu m	Comment	OSHA Value Comparison[c]
Manganese, as Mn				
Dust & compounds	-	5	Ceiling	S
Fume	-	1		
Manganese cyclopentadienyl tricarbonyl, as Mn	-	0.1	Skin	
Manganese tetroxide	-	1		
Marble/calcium carbonate	-	10	Nuisance particulate	
Mercury, as Hg			Skin	
Alkyl compounds	-	0.01		
All forms except alkyl				
Vapor	-	0.05		
Aryl & inorganic compounds	-	0.1		
Mesityl oxide	15	60		L
Methyacrylic acid	20	70		
Methomyl	-	2.5	Skin	
Methoxychlor	-	10		L
2-Methoxyethanol	25	80	Skin	S
Proposed	5	16	Skin	L
2-Methoxyethyl acetate	25	120	Skin	
Proposed	5	24	Skin	
4-Methoxyphenol	-	5		
Methyl acetate	200	610		S
Methyl acetylene	1000	1650		S
Methyl acetylene-propadiene mixture	1000	1800		S
Methyl acrylate	10	35	Skin	S
Methylacrylonitrile	1	3	Skin	
Methylal	1000	3100		S
Methyl alcohol	200	260	Skin	S
Methylamine	10	12		S
Methyl n-amyl ketone	50	235		L
N-Methyl aniline	0.5	2	Skin	L
Methyl bromide	5	20	Skin	L
Methyl n-butyl ketone	5	20		L
Methyl chloride	50	105		
Methyl chloroform	350	1900		S
Methyl 2-cyanoacrylate	2	8		
Methylcyclohexane	400	1600		L
Methylcyclohexanol	50	235		L

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S^{a,b}
(Continued)

Compound	TWA ppm	TWA mg/cu m	Comment	OSHA Value Comparison^{c}
o-Methylcyclohexanone	50	230	Skin	L
Methylcyclopentadienyl manganese tricarbonyl, as Mn	–	0.2	Skin	
Methyl demeton	–	0.5	Skin	
Methylene bisphenyl isocyanate	0.02	0.2	Ceiling	S
Methylene chloride	100	350		
4,4'-Methylene bis (2-chloroaniline)	0.02	0.22	Skin;Suspect carcinogen	
Methylene bis (4-cyclohexlyisocyanate)	0.01	0.11	Ceiling	
4,4-Methylene dianiline	0.1	0.8	Skin	
Methyl ethyl ketone	200	590		S
Methyl ethyl ketone peroxide	0.2	1.5	Ceiling	
Methyl formate	100	250		S
Methyl hydrazine	0.2	0.35	Skin; Ceiling; Suspect carcinogen	S
Methyl iodide	2	10	Skin;Suspect carcinogen	L
Methyl isoamyl ketone	50	240		
Methyl isobutyl carbinol	25	100	Skin	S
Methyl isobutyl ketone	50	205		L
Methyl isocyanate	0.02	0.05	Skin	S
Methyl isopropyl ketone	200	705		
Methyl mercaptan	0.5	1		L
Methyl methacrylate	100	410		S
Methyl parathion	–	0.2	Skin	
Methyl propyl ketone	200	700		S
Methyl silicate	1	6		
alpha-Methyl styrene	50	240		L
Metribuzin (Proposed)	–	5		
Mevinphos	0.01	0.1	Skin	
Molybdenum, as Mo				
Soluble compounds	–	5		S
Insoluble compounds	–	10		L
Monocrotophos	–	0.25		
Morpholine	20	70	Skin	S
Nalid	–	3		
Naphthalene	10	50		S
beta-Naphthylamine	–	–	Human carcinogen	

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]
(Continued)

Compound	TWA		Comment	OSHA Value Comparison[c]
	ppm	mg/cu m		
Nickel carbonyl, as Ni	0.05	0.35		H
Nickel, as Ni				
Metal	-	1		S
Soluble compounds	-	0.1		L
Nicotine	-	0.5	Skin	S
Nitrapyrin	-	10		
Nitric oxide	2	5		S
Nitric acid	25	30		S
p-Nitroaniline	-	3	Skin	L
Nitrobenzene	1	5	Skin	S
p-Nitrochlorobenzene	-	1	Skin	S
Proposed	0.5	3	Skin	L
4-Nitrodiphenyl	-	-	Human carcinogen	
Nitroethane	100	310		S
Nitrogen dioxide	3	6		L
Nitrogen trifluoride	10	30		S
Nitroglycerin	0.05	0.5	Skin	L
Nitromethane	100	250		S
1-Nitropropane	25	90		S
2-Nitropropane	25	90	Ceiling;Susp. carcinogen	S
Proposed	10	35	Suspect carcinogen	L
N-Nitrosodimethylamine	-	-	Skin;Suspect carcinogen	
Nitrotoluene	2	11	Skin	L
Nonane	200	1050		
Octachloronaphthalene	-	0.1	Skin	S
Octane	300	1450		L
Oil mist, mineral	-	5		S
Osmium tetroxide, as Os	-	0.002		S
Oxalic acid	-	1		S
Oxygen difluoride	0.05	0.1		S
Ozone	0.1	0.2		S
Paraffin wax fume	-	2		
Paraquat, respirable size	-	0.1		S
Parathion	-	0.1	Skin	S
Pentaborane	0.005	0.01		S
Pentachloronaphthalene	-	0.5		S
Pentachlorophenol	-	0.5	Skin	S
Pentaerythritol	-	10	Nuisance particulate	
Pentane	600	1800		L
Perchloroethylene				
Proposed	50	335		

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]
(Continued)

Compound	TWA		Comment	OSHA Value Comparison[c]
	ppm	mg/cu m		
Perchloromethyl mercaptan	0.1	0.8		S
Perchloroyl fluoride	3	14		S
Persulfates,alkali metal, as S208; (Proposed)	8	2		
Phenol	5	19	Skin	S
Phenothiazine	-	5	Skin	
N-Phenyl-beta-naphthylamine	-	-	Suspect carcinogen	
p-Phenylene diamine	-	0.1	Skin	S
Phenyl ether vapor	1	7		S
Phenyl glycidyl ether	1	6		L
Phenylhydrazine	5	20	Skin	S
Proposed	5	20	Skin;Suspect carcinogen	L
Phenyl mercaptan	0.5	2		
Phenylphosphine	0.05	0.25	Ceiling	
Phorate	-	0.05	Skin	
Phosgene	0.1	0.4		S
Phosphine	0.3	0.4		S
Phosphoric acid	-	1		S
Phosphorus (yellow)	-	0.1		S
Phosphorus oxychloride	0.1	0.6		
Phosphorus pentachloride	0.1	1		S
Phosphorus pentasulfide	-	1		S
Phosphorus trichloride	0.2	1.5		L
Phthalic anhydride	1	6		L
m-Phthalodinitrile	-	5		
Picloram	-	10		
Picric acid	-	0.1	Skin	S
Pindone	-	0.1		
Piperazine dihydrochloride	-	5		
Plaster of Paris	-	10	Nuisance particulate	
Platinum				
Metal	-	1		
Soluble salts, as Pt	-	0.002		S
Potassium hydroxide	-	2	Ceiling	
Propane sultone	-	-	Suspect carcinogen	
Propargyl alcohol	1	2		
beta-Propiolactone	0.5	1.5	Suspect carcinogen	
Propionic acid	10	30		
Propoxur	-	0.5		

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]
(Continued)

Compound	TWA ppm	TWA mg/cu m	Comment	OSHA Value Comparison[c]
n-Propyl acetate	200	840		S
Propyl alcohol	200	500	Skin	S
n-Propyl nitrate	25	105		S
Propylene dichloride	75	350		S
Propylene glycol				
dinitrate (Proposed)	0.05	0.3	Skin	
Propylene glycol				
monomethyl ether	100	360		
Propyleneimine	2	5	Skin;Suspect carcinogen	S
Propylene oxide	20	50		L
Pyrethrum	-	5		S
Pyridine	5	15		S
Quinone	0.1	0.4		S
Resorcinol	10	45		
Rhodium				
Metal	-	1		H
Insoluble compounds,				
as Rh	-	1		
Proposed	-	1		
Soluble compounds,				
as Rh	-	0.001		S
Proposed	-	0.01		L
Ronnel	-	10		L
Rotenone (commercial)	-	5		S
Rouge	-	10	Nuisance particulate	
Rubber solvent (Naphtha)	400	1600		
Selenium compounds, as Se	-	0.2		S
Selenium hexafluoride,				S
as Se	0.05	0.2		S
Sesone	-	10		
Silicone	-	10	Nuisance particulate	
Silicone carbide	-	10	Nuisance particulate	
Silicone tetrahydride	5	7		
Silver				
Metal	-	0.1		H
Soluble compounds	-	0.01		S
Sodium azide	0.1	0.3	Ceiling	
Sodium bisulfite	-	5		
Sodium fluoroacetate	-	0.05	Skin	S
Sodium hydroxide	-	2	Ceiling	S
Sodium metabisulfite	-	5		

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]
(Continued)

Compound	TWA ppm	TWA mg/cu m	Comment	OSHA Value Comparison[c]
Starch	-	10	Nuisance particulate	
Stibine	0.1	0.5		S
Stoddard solvent	100	525		L
Strychnine	-	0.15		S
Styrene monomer	50	215		
Sucrose	-	10	Nuisance particulate	
Sulfotep	-	0.2	Skin	
Sulfur dioxide	2	5		L
Sulfur hexafluoride	1000	6000		S
Sulfuric acid	-	1		S
Sulfur monochloride	1	6		S
Sulfur pentafluoride	0.025	0.25		S
Sulfur tetrafluoride	0.1	0.4		
Sulfuryl fluoride	5	20		S
Sulprofos (Proposed)	-	1		
2,4,5-T	-	10		S
Tantalum	-	5		S
Tellurium & Compounds, as Te	-	0.1		S
Tellurium hexafluoride as Te	0.02	0.2		S
Temephos	-	10		
TEPP	0.004	0.05	Skin	S
Terphenyls	0.5	5	Ceiling	L
1,1,1,2-Tetrachloro-2,2-difluoroethane	500	4170		S
1,1,2,2-Tetrachloro-1,2-difluoroethane	500	4170	Skin	S
1,1,2,2-Tetrachloroethane	1	7	Skin	L
Tetrachloronaphthalene	-	2		S
Tetraethyl lead, as Pb	-	0.1	Skin	S
Tetrahydrofuran	200	590		S
Tetramethyl lead, as Pb	-	0.15	Skin	H
Tetramethyl succino nitrile	0.5	3	Skin	S
Tetranitromethane	1	8		S
Tetrasodium pyrophosphate	-	5		
Tetryl (2,4,6-trinitrophenyl-methylnitramine)	-	1.5	Skin	S
Thallium				
Soluble compounds, as T	-	0.1	Skin	S

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S^{a,b}
(Continued)

Compound	TWA		Comment	OSHA Value Comparison^{c}
	ppm	mg/cu m		
4,4'-Thiobis(6-tertbutyl-m-cresol)	-	10		
Thioglycolic acid	1	5		
Thiram	-	5		S
Tin				
Metal	-	2		
Oxide & inorganic compounds, except SnO4, as Sn	-	2		S
Organic compounds, as Sn	-	0.1	Skin	S
Titanium dioxide	-	10	Nuisance particulate	L
o-Tolidine	-	-	Skin; Suspect carcinogen	
Toluene	100	375		
Toluene-2,4-diisocyanate	0.005	0.04		L
o-Toluidine	2	9	Skin	L
Proposed	2	9	Skin;Suspect carcinogen	
Tributyl phosphate	0.2	2.5		L
Trichloroacetic acid	1	5		
1,2,4-Trichlorobenzene	5	40	Ceiling	
1,1,2-Trichloroethane	10	45	Skin	S
Trichloroethylene				
Proposed	50	270		
Trichlorofluoromethane	1000	5600	Ceiling	
Trichloronaphthalene	-	5		S
1,2,3-Trichloropropane	50	300		S
1,1,2-Trichloro-1,2,2-trifluoroethane	1000	7600		S
Triethylamine	10	40		L
Trifluorobromomethane	1000	6100		S
Trimellitic anhydride	0.005	0.04		
Trimethylamine	10	24		
Trimethyl benzene	25	125		
Trimethyl phosphite	2	10		
2,4,6-Trinitrotoluene	-	0.5	Skin	L
Triorthocresyl phosphate	-	0.1		S
Triphenyl amine	-	5		
Triphenyl phosphate	-	3		S
Tungsten, as W				
Insoluble compounds	-	5		
Soluble compounds	-	1		
Turpentine	100	560		S

(Continued)

TABLE B-5. 1983-1984 ACGIH RECOMMENDED TLV'S[a,b]
(Continued)

Compound	TWA ppm	TWA mg/cu m	Comment	OSHA Value Comparison[c]
Uranium (natural), as U				
Soluble compounds	-	0.2		H
Insoluble compounds	-	0.2		S
Valeraldehyde	50	175		
Vanadium, as V205, Respirable dust and fume	-	0.05		L
Vegetable oil mists	-	10	Nuisance particulate	
Vinyl acetate	10	30		
Vinyl bromide	5	20	Suspect carcinogen	
Vinyl chloride	5	10	Human carcinogen	
Vinyl cyclohexene dioxide	10	60	Suspect carcinogen	
Vinylidene chloride	10	40		
Proposed	5	20		
Vinyl toluene	50	240		L
VM & P Naphtha	300	1350		
Warfarin	-	0.1		S
Wood dust				
Certain hard woods as beech & oak	-	1		
Soft wood	-	5		
Xylene (o-,m-,p-isomers)	100	435		S
m-Xylene alpha,alpha' -diamine	-	0.1	Skin; Ceiling	
Xylidine	2	10	Skin	L
Yttrium	-	1		S
Zinc chloride fume	-	1		S
Zinc chromate, as Cr	-	0.05	Suspect carcinogen	
Zinc oxide				
Fume	-	5		S
Dust	-	10	Nuisance particulate	
Zinc stearate	-	10	Nuisance particulate	
Zirconium compounds, as Z	-	5		

FOOTNOTES FOR TABLE B-5

a) Threshold Limit Values (TLVs) adopted by the Americam Conference of Governmental Industrial Hygienists. ISBN: 0-936712-45-7. Cincinnati, Ohio, 1983.

b) Time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which all workers may be repeatedly exposed, wothout adverse effect. Ceiling values should not be exceeded even instantaneously.

c) 1983-1984 ACGIH recommended concentrations are compared to OSHA regulations adopted in 1964.
S means recommendation is same as OSHA value.
L means recommendation is lower than OSHA value.
H means recommendation is higher than OSHA value.

TABLE B-6. PRIMARY DRINKING WATER REGULATIONS: INORGANICS LEVELS[a] (40 CFR, PART 141)

Contaminant	Level, mg/L
Arsenic	0.05
Barium	1
Cadmium	0.010
Chromium	0.05
Fluoride	2.4-1.4[b]
Lead	0.05
Mercury	0.002
Nitrate (as N)[c]	10
Selenium	0.01
Silver	0.05

[a] Not to be exceeded in community water systems

[b] Not to be exceeded level decreases with increasing annual average daily temperature

[c] Applicable to community and noncommunity water systems.

TABLE B-7 PRIMARY DRINKING WATER REGULATIONS: ORGANICS LEVELS[a] (40 CFR, PART 141)

Contaminant	Maximum Level mg/L
(a) Chlorinated hydrocarbons	
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
(b) Chlorophenoxys	
2,4-D, (2,4-Dichlorophenoxyacetic acid)	0.1
2,4,5-TP (Silvex) (2,4,5-Trichlorophenoxy-propionic acid)	0.01
(c) Total trihalomethanes	0.10

[a] Not to be exceeded

TABLE B-8 PRIMARY DRINKING WATER REGULATIONS: RADIONUCLIDES LEVELS (40 CFR, PART 141)

Radionuclide	Critical organ	Maximum level pCi/L
Tritium	Total body	20,000
Strontium-90	Bone marrow	8

TABLE B-9 NATIONAL SECONDARY DRINKING WATER STANDARDS (40 CFR, PART 143)

Contaminant	Maximum level
Chloride	250 mg/L
Color	15 color units
Copper	1 mg/L
Corrosivity	Noncorrosive
Foaming agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	Threshold Odor Number 3
pH	6.5 - 8.5
Sulfate	250 mg/L
TDS	500 mg/L
Zinc	5 mg/L

TABLE B-10
1980 WATER QUALITY CRITERIA BASED ON HEALTH FOR NONCARCINOGENIC (THRESHOLD) POLLUTANTS

Substance	Criterion[a] (μg/L)	Comment
Acenaphthalene	20	Organoleptic properties
Acrolein	320	
Antimony	146	
Cadmium	10	
Chlorinated ethanes	20	Organoleptic properties
Chlorobenzene	488	
bis-(2-Chloroisopropyl)ether	34.7	
Chlorophenols (all mono isomers)	0.1	Organoleptic properties
Chromium (VI)	50	
Chromium (III)	170,000	
Copper	1,000	
Cyanide	200	
Dibutylphthalate	34,000	
Dichlorobenzenes (all isomers)	400	
2,3-Dichlorophenol	0.04	Organoleptic properties
2,4-Dichlorophenol	3,090	
	0.3	Organoleptic properties
2,5-Dichlorophenol	0.5	Organoleptic properties
2,6-Dichlorophenol	0.2	Organoleptic properties
3,4-Dichlorophenol	0.3	Organoleptic properties
Dichloropropenes	87	
Di-2-ethylhexyl phthalate	15,000	
Diethylphthalate	350,000	
2,4-Dimethylphenol	400	Organoleptic properties
Dimethylphthalate	313,000	
2,4-Dinitro-o-cresol	13.4	
Dinitrophenol	70	
Endosulfan	74	
Endrin	1	
Ethylbenzene	1,400	
Fluoranthene	42	
Hexachlorocyclopentadiene	206	
	1.0	Organoleptic properties
Isophorone	5,200	
Lead	50	
Mercury	0.144	
2-Methyl-4-chlorophenol	1,800	Organoleptic properties
3-Methyl-4-chlorophenol	3,000	Organoleptic properties
3-Methyl-6-chlorophenol	20	Organoleptic properties
Nickel	13.4	
Nitrobenzene	19,800	
	30	Organoleptic properties
Pentachlorophenol	1,010	
	30	Organoleptic properties

TABLE B-10 (continued)

Substance	Criterion[a] (μg/L)	Comment
Phenol	3,500	
	300	Organoleptic properties
Selenium	10	
Silver	50	
2,3,4,6-Tetrachlorophenol	1.0	Organoleptic properties
Thallium	13	
Toluene	14,300	
1,1,1-Trichloroethane	18,400	
2,4,5-Trichlorophenol	2,600	
	1.0	Organoleptic properties
2,4,6-Trichlorophenol	2	Organoleptic properties
Zinc	5,000	Organoleptic properties

[a] Unless otherwise indicated, the criterion is based on ingestion of water and contaminated organisms.

TABLE B-11. WATER QUALITY CRITERIA FOR NONTHRESHOLD POLLUTANTS[a]

Substance	Level in water (μg/L) estimated to result in incremental increase of cancer over 70 years at risk of 1 in 100,000
Organics (Other than halogenated organics and pesticides)	
Acrylonitrile	0.58
1,2-Diphenylhydrazine	0.422
N-Nitrosodimethylamine	0.014
N-Nitrosodiethylamine	0.008
N-Nitrosodibutylamine	0.064
N-Nitrosodiphenylamine	49
N-Nitrosopyrrolidine	0.160
Benzene	6.6
Benzidine	0.0012
2,4-Dinitrotoluene	1.1
Polynuclear aromatic hydrocarbons	0.028
Halogenated Aliphatic Hydrocarbons	
Halomethanes (Chloromethane, bromomethane, dichloromethane, bromodichloromethane, tribromomethane, dichlorodifluoromethane, trichlorofluoromethane, or combinations)	
Chloroform	1.9
Carbon tetrachloride	4.0
1,2-Dichloroethane	9.4
1,1,2-Trichloroethane	6.0
1,1,2,2-Tetrachloroethane	1.7
Hexachloroethane	19
Vinyl chloride	20
1,1-Dichloroethylene	0.33
Trichloroethylene	27
Tetrachloroethylene	8
Hexachlorobutadiene	4.47
Other Chlorinated Organics	
bis(Chloromethyl)ether	0.0000038
bis(2-Chloroethyl)ether	0.3
Hexachlorobenzene	0.0072
Polychlorinated biphenyls	0.00079
2,4,6-Trichlorophenol	12
Dichlorobenzidine	0.103
2,3,7,8-tetrachlorodibenzo-p-dioxin	0.00000013

(Continued)

TABLE B-11. (Continued)

Substance	Level in water (μg/L) estimated to result in incremental increase of cancer over 70 years at risk of 1 in 100,000
Pesticides	
Aldrin	0.00079
Dieldrin	0.00071
Chlordane	0.0046
DDT	0.00024
Heptachlor	0.00278
Hexachlorocyclohexanes	
alpha-HCH	0.092
beta-HCH	0.163
tech-HCH	0.123
gamma-HCH	0.186
Toxaphene	0.0071
Inorganics	
Arsenic	0.022
Asbestos	300,000 fibers per liter
Beryllium	0.068

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[a] The U.S. EPA recognizes that for the maximum protection of human health from the potential carcinogenic effects of these pollutants the ambient water concentration should be zero based on the assumption of nonthreshold behavior. However, as the zero level may not be attainable at the present time, levels which may result in a specified incremental increase in risk have been estimated to serve as criteria. (U.S. EPA Federal Register, November 28, 1980).

TABLE B-12. WATER QUALITY CRITERIA FOR PROTECTION OF AQUATIC LIFE (EXCLUDING PESTICIDES AND HALOGENATED SPECIES[a])

Pollutant	Criteria	Ref.[b]
Acenaphthene	Acute toxicity occurs as low as 1,700 μg/L in freshwater species and 970 μg/L in saltwater species. Freshwater algae are affected by 520 μg/L, saltwater algae at 500 μg/L. Chronic toxicity occurs in saltwater species as low as 710 μg/L.	1
Acrolein	Acute toxicity occurs as low as 68 μg/L in freshwater species and 55 μg/L in saltwater species. Chronic toxicity occurs in freshwater species as low as 21 μg/L.	1
Acrylonitrile	Acute toxicity occurs as low as 7,550 μg/L in freshwater species. Mortality occurred in freshwater fish exposed for 30 days at 2,600 μg/L.	1
Aluminum	For protection of saltwater species an application factor of 0.01 is recommended to be applied to the 96-hour LC50 for sensitive organisms. Concentrations exceeding 1,500 μg/L constitute a hazard in the marine environment, and levels less than 200 μg/L present minimal risk of deleterious effects.	2
Ammonia (un-ionized)	For marine species, an application factor of 0.1 is recommended. Concentrations equal to or exceeding 400 μg/L constitute a hazard to marine biota. Levels below 10 μg/L present minimal risk of deleterious effects. (Insufficient data for 1984 Criterion.)	2
Antimony	Acute toxicity occurs as low as 9,000 μg/L in freshwater species and is toxic to freshwater algae at 610 μg/L. Chronic toxicity occurs in freshwater species as low as 1,600 μg/L.	1
	For protection of saltwater species an application factor of 0.01 is recommended to be applied to the 96-hour LC50 for sensitive organisms. Concentrations exceeding 0.2 μg/L constitute a hazard in the marine environment.	2

(continued)

TABLE B-12 (continued)

Pollutant	Criteria	Ref.[b]
Arsenic[c] (trivalent)	For freshwater aquatic life in each 30 consecutive days the average concentration of arsenic shall not exceed 72 μg/L, the maximum concentration shall not exceed 140 μg/L, and the concentration may be between 72 μg/L and 140 μg/L for up to 96 hours. For saltwater aquatic life in each 30 consecutive days the average concentration of arsenic shall not exceed 63 μg/L, the maximum concentration shall not exceed 120 μg/L, and the concentration may be between 63 μg/L and 170 μg/L for up to 96 hours.	3
Barium	For protection of saltwater species an application factor of 0.05 is recommended to be applied to the 96-hour LC50 for sensitive organisms. Concentrations equal to or exceeding 1,000 μg/L constitute a hazard in the marine environment, and levels less than 500 μg/L present minimal risk of deleterious effects.	2
Benzene	Acute toxicity occurs as low as 5,300 μg/L in freshwater species and 5,100 μg/L in saltwater species. Adverse effects occur in saltwater fish exposed for 168 days as low as 700 μg/L.	1
Benzidine	Acute toxicity occurs as low as 2,500 μg/L in freshwater species.	1
Beryllium	Acute toxicity occurs as low as 130 μg/L in freshwater species. Chronic toxicity occurs in freshwater species as low as 5.3 μg/L. Hardness has a substantial effect on acute toxicity.	1
	For protection of saltwater species an application factor of 0.01 is recommended to be applied to the 96-hour LC50 for sensitive organisms. Concentrations equal to or exceeding 1,500 μg/L constitute a hazard in the marine environment, and levels less than 100 μg/L present minimal risk of deleterious effects.	2

(continued)

TABLE B-12 (continued)

Pollutant	Criteria	Ref.[b]
Boron	For protection of saltwater species an application factor of 0.1 is recommended to be applied to the 96-hour LC50 for sensitive organisms. Concentrations equal to or exceeding 5,000 μg/L constitute a hazard in the marine environment, and levels less than 5,000 μg/L present minimal risk of deleterious effects.	2
Bromate	It is recommended that ionic bromine in the form of bromate be maintained below 100,000 μg/L in the marine environment.	2
Bromine	It is recommended that free (molecular) bromine in the marine environment not exceed 100 μg/L.	(free)
Cadmium	For freshwater aquatic life, the concentration of active cadmium shall not exceed a level equal to 1.16 (ln hardness mg/L) - 3.841 due to acute and chronic toxicities being nearly the same. For saltwater aquatic life in each 30 consecutive days the average concentration of cadmium shall not exceed 12 μg/L, the maximum concentration shall not exceed 38 μg/L, and the concentration may be between 12 μg/L and 38 μg/L for up to 96 hours.	3
Chlorine	For freshwater aquatic life in each 30 consecutive days the average concentration of chlorine shall not exceed 8.3 μg/L, the maximum concentration shall not exceed 14 μgl/L, and the concentration may be between 8.3 μg/L and 14 μg/L for up to 96 hours. For saltwater aquatic life in each 30 consecutive days the average concentration of chlorine shall not exceed 7.4 μg/L, the maximum concentration shall not exceed 13 μg/L, and the concentration may be between 7.4 μg/L and 13 μg/L for up to 96 hours.	3
Chromium[c] (hexavalent)	For freshwater aquatic life in each 30 consecutive days the average concentration of chromium shall not exceed 7.2 μg/L, the maximum concentration shall not exceed 11 μg/L, and the contration may be between 7.2 μg/L and 1100 μg/L for up to 96 hours.	3

(continued)

TABLE B-12 (continued)

Pollutant	Criteria	Ref.[b]
Chromium[c] (hexavalent)	For saltwater aquatic life in each 30 consecutive days the average concentration of chromium shall not exceed 5.4 μg/L, the maximum concentration shall not exceed 1200 μg/L, and the concentration may be between 5.4 μg/L and 1200 μg/L for up to 96 hours.	
Chromium[c] (trivalent)	For freshwater aquatic life in each 30 consecutive days the average concentration of chromium shall not exceed 0.819 (ln hardness mg/L) to 537, the maximum concentration shall not exceed 0.819 (ln hardness mg/L) + 3.568. No saltwater criterion were derived, but levels of 10,300 μg/L are lithal to the eastern oyster.	3
Copper[c]	For freshwater aquatic life in each 30 consecutive days the average concentration of copper shall not exceed 0.905 (ln hardness) - 1.705, the maximum concentration shall not exceed 0.905 (ln hardness mg/L + 3.568, and the concentration may be between the average and the maximum for up to 96 hours. For saltwater aquatic life in each 30 consecutive days the average concentration of copper shall not exceed 2 μg/L, the maximum concentration shall not exceed 3.2 μg/L, and the concentration may be between 2 μg/L and 3.2 g/L for up to 96 hours.	3
Cyanides (sum of HCN and CN^-)	For freshwater aquatic life in each 30 consecutive days the average concentration of cyanides shall not exceed 4.2 μg/L, the maximum concentration shall not exceed 22 μg/L, and the concentration may be between 4.2 μg/L and 22 μg/L for up to 96 hours. For saltwater aquatic life in each 30 consecutive days the average concentration of cyanides shall not exceed 0.57 μg/L, the maximum concentration shall not exceed 1 μg/L, and the concentration may be between 0.57 μg/L and 1 g/L for up to 96 hours.	3
2,4-Dinitrotoluene	Acute toxicity occurs as low as 330 μg/L in freshwater species and 590 μg/L in saltwater species.	1

(continued)

TABLE B-12 (continued)

Pollutant	Criteria	Ref.[b]
2,4-Dinitrotoluene (cont'd.)	Chronic toxicity occurs in freshwater species as low as 230 µg/L. A decrease in saltwater algal cell numbers occurs as low as 370 µg/L.	
1,2-Diphenylhydrazine	Acute toxicity occurs as low as 270 µg/L in freshwater species.	1
Ethylbenzene	Acute toxicity occurs as low as 32,000 µg/L in freshwater species and 430 µg/L in saltwater species.	1
Fluoranthene	Acute toxicity occurs as low as 3,980 µg/L in freshwater species and 40 µg/L in saltwater species. Chronic toxicity occurs in saltwater species as low as 16 µg/L.	1
Fluorides	For protection of saltwater species an application factor of 0.1 is recommended to be applied to the marine 96-hour LC50. Concentrations equal to or exceeeding 1,500 µg/L constitute a hazard to the marine environment, and levels less than 500 µg/L present minimal risk of deleterious effects.	2
Iron	Concentrations equal to or exceeding 300 µg/L constitute a hazard to the marine environment, and levels less than 50 µg/L present minimal risk of deleterious effects.	2
Isophorone	Acute toxicity occurs as low as 117,000 µg/L in freshwater species and 12,900 µg/L in saltwater species.	1
Lead[c]	For freshwater aquatic life in each 30 consecutive days the average concentration of lead shall not exceed 1.34 (ln hardness mg/L) - -5.245, the maximum concentration shall not exceed 1.34 (ln hardness mg/L) - 2.014, and the concentration may be between the average and the maximum for up to 96 hours. For saltwater aquatic life in each 30 consecutive days the average concentration of lead shall not exceed 8.6 µg/L, the maximum concentration shall not exceed 220 µg/L, and the concentration may be between 8.6 µg/L and 220 µg/L for up to 96 hours.	3

(continued)

TABLE B-12 (continued)

Pollutant	Criteria	Ref.[b]
Manganese	For protection of saltwater species an application factor of 0.02 is recommended to be applied to the marine 96-hour LC50. Concentrations equal to or exceeding 100 µg/L constitute a hazard to the marine environment, and levels less than 20 µg/L present minimal risk.	2
Mercury[c]	For freshwater aquatic life in each 30 consecutive days the average concentration of mercury shall not exceed 0.2 µg/L, the maximum concentration shall not exceed 1.1 µg/L, and the concentration may be between 0.2 µg/L and 1.1 µg/L for up to 96 hours. For saltwater aquatic life in each 30 consecutive days the average concentration of mercury shall not exceed 0.1 g/L, the maximum concentration shall not exceed 1.9 µg/L, and the concentration may be between 0.1 g/L and 1.9 g/L for up to 96 hours.	3
Molybdenum	It is recommended that the concentration in seawater should not exceed 0.05 of the 96-hour LC50 at any time for the most sensitive species and that the 24-hour average not exceed 0.02 of the 96-hour LC50.	1
Naphthalene	Acute toxicity occurs as low as 2,300 µg/L in freshwater species and 2,350 µg/L in saltwater species. Chronic toxicity in freshwater species occurs as low as 620 µg/L.	1
Nickel	For freshwater aquatic life, total recoverable nickel should not exceed 1,100 µg/L at any time assuming a hardness of 50 mg/L as $CaCO_3$. For saltwater species the concentration should not exceed 140 µg/L at any time. The 24-hour average freshwater criterion is 56 µg/L for a hardness of 50 mg/L. The 24-hour saltwater criterion is 7.1 µg/L.	1
Nitrobenzene	Acute toxicity occurs as low as 27,000 µg/L in freshwater species and 6,680 µg/L in saltwater species.	1

(continued)

TABLE B-12 (continued)

Pollutant	Criteria	Ref.[b]
Nitrophenols	Acute toxicity occurs as low as 230 μg/L in freshwater species and 4,850 μg/L in saltwater species. Toxicity to freshwater algae occurs as low as 150 μg/L.	1
Nitrosamines	Acute toxicity occurs as low as 5,850 μg/L in freshwater species and 3,300,000 μg/L in saltwater species.	1
Phenol	Acute toxicity occurs as low as 10,200 μg/L in freshwater species and 5,800 μg/L in saltwater species. Chronic toxicity occurs in freshwater species as low as 2,560 μg/L.	1
2,4-Dimethyl phenol	Acute toxicity occurs as low as 2,120 μg/L in freshwater species.	1
Phenolics (Phenolic compounds)	For freshwater species, an application factor of 0.05 is recommended to be applied to the 96-hour LC50 for important sensitive species. No concentration greater than 100 μg/L is recommended at any time or place.	2
Phthalate Esters	Acute toxicity occurs as low as 940 μg/L freshwater species and 2,944 μg/L in saltwater species. Chronic toxicity occurs in freshwater species as low as 3 μg/L. Toxicity to one species of saltwater algae occurs as low as 3.4 μg/L.	1
Phosphorus (elemental)	For protection of saltwater species an application factor of 0.01 is recommended to be applied to the marine 96-hour LC50. Concentrations equal to or exceeding 1 μg/L constitute a hazard to the marine environment.	2
Polychlorinated biphenyls	Acute toxicity probably will only occur at concentrations above 2.0 μg/L for freshwater species and above 10 μg/L for saltwater species. The 24-hour average freshwater criterion is 0.014 μg/L. The 24-hour saltwater criterion is 0.030 μg/L.	1

(continued)

TABLE B-12 (continued)

Pollutant	Criteria	Ref.[b]
Polynuclear Aromatic Hydrocarbons	Acute toxicity occurs as low as 300 μg/L for saltwater species.	1
Selenium (as inorganic selenite, Se^{-2})	For freshwater aquatic life, total recoverable inorganic selenite should not exceed 260 μg/L at any time. For saltwater species, the concentration should not exceed 410 μg/L at any time.	1
Selenium (as inorganic selenite, Se^{-2})	The 24-hour averge freshwater criterion is 35 μg/L. The 24-hour saltwater criterion is 54 μg/L.	
Selenium (as inorganic selenate, Se^{+4})	Acute toxicity occurs as low as 760 μg/L in freshwater species.	1
Silver	For freshwater aquatic life, total recoverable silver should not exceed 1.2 μg/L at any time, assuming a hardness of 50 mg/L as $CaCO_3$. For saltwater species the concentration should not exceed 2.3 μg/L at any time. Chronic toxicity in freshwater species occurs as low as 0.12 μg/L.	1
Sulfide	For protection of saltwater species an application factor of 0.1 is recommended to be applied to the marine 96-hour LC50. Concentrations equal to or exceeding 10 μg/L constitute a hazard to the marine environment, and levels less than 5 μg/L present minimal risk of deleterious effects with the pH maintained within a range of 6.5 to 8.5.	2
Hydrogen Sulfide (undissociated)	For freshwater species, a level assumed to be safe for all aquatic organisms including fish is 2 μg/L. It is recommended that the concentration of total sulfides not exceed 2 μg/L at any time or place.	2
Thallium	Acute toxicity occurs as low as 1,400 μg/L in freshwater species and as low as 2,130 μg/L in saltwater species. Chronic toxicity occurs as low as 40 μg/L in freshwater species, and one freshwater fish is affected after 2,600 hours as low as 20 μg/L.	1

(continued)

TABLE B-12 (continued)

Pollutant	Criteria	Ref.[b]
	For salt species, because of a chronic effect of long-term exposure, tests should be conducted for at least 20 days to determine harmful, sublethal concentrations. The concentration in seawater should not exceed 0.05 of this concentration. Concentrations equal to or exceeding 100 μg/L constitute a hazard to the marine environment, and levels less than 50 μg/L present minimal risk of deleterious effects.	2
Toluene	Acute toxicity occurs as low as 17,500 μg/L in freshwater species and as low as 6,300 μg/L in saltwater species. Chronic toxicity occurs in saltwater species as low as 5,000 μg/L.	1
Uranium	For protection of saltwater species an application factor of 0.01 is recommended to be applied to the marine 96-hour LC50. Concentrations equal to or exceeding 500 μg/L constitute a hazard to the marine environment, and levels less than 100 μg/L present minimal risk of deleterious effects.	2
Vanadium	It is recommended that the concentration of seawater not exceed 0.05 of the 96-hour LC50 for the most sensitive species.	2
Zinc	For freshwater aquatic life, total recoverable zinc should not exceed 180 μg/L at any time, assuming a hardness of 50 mg/L as $CaCO_3$. For saltwater species the concentration should not exceed 170 μg/L at any time. The 24-hour average criterion for freshwater is 47 μg/L for a hardness of 50 mg/L. The 24-hour saltwater criterion is 58 μg/L.	1

(continued)

TABLE B-12 (continued)

Footnotes:

[a] In addition to the pollutants listed in the Table, certain pesticides and numerous halogenated organics are addressed by the U.S. EPA 1980 Water Quality Criteria. Criteria for protection of aquatic life and/or levels at which toxicity occurs are specified.

Pesticides

Aldrin/dieldrin
Chlordane
DDT
Endosulfan
Endrin
Heptachlor
Toxaphene

Halogenated Organics

Carbon tetrachloride
Chlorinated benzenes
Chlorinated ethanes
Chloroalkyl ethers
Chlorinated naphthalene
Chlorinated phenols
Chloroform
2-Chlorophenol
Dichlorobenzenes
Dichlorobenzidine
Dichloroethylenes
2,4-Dichlorophenol
Dichloropropanes/propenes
Haloethanes
Halomethane
Hexachlorobutadiene
Hexachlorocyclohexane
Hexachlorocyclopentadiene
Pentachlorophenol
Tetrachloroethylene
Trichloroethylene
Vinyl chloride

[b] References:

[1] U.S. EPA, Water Quality Criteria, Federal Register, November 28, 1980 (with updates).

[2] NAS/NAE. Water Quality Criteria 1972. Prepared for the U.S. Environmental Protection Agency by the National Academy of Sciences, National Academy of Engineering, National Academy of Sciences, Washington, D.C., EPA-R3-73-933.

[3] U.S. EPA (1984) Water Quality Criteria; Request for Comments, Federal Register, Volume 49, No. 26, 4551-4554, February 7, 1984.

[c] For arsenic; chromium, cooper, lead, and mercury, the chemical is defined as the dissolved fraction that passes through a 0.45 μm membrane filter.

TABLE B-13. NATIONAL ACADEMY OF SCIENCES AND EPA SNARLS (SUGGESTED NO ADVERSE RESPONSE LEVELS) AND OTHER UNENFORCEABLE ADVISORY LEVELS

	Short-Term Dose in mg/L (Days)	Long-Term Dose (Chronic) in ug/L
1. Acrylonitrile		
NAS		1.3 x 10^{-6} cancer risk per µg/L
EPA	0.035 (10); 0.003 (30)	
2. Benzene		
NAS	12.6 (7)	
EPA	0.35 (7)	0.67 µg/L for 10^{-6} cancer risk, calculated
3. Benzene hexachloride, or BHC		
NAS	3.5 (1); 0.5 (7)	
4. Benzo(a)pyrene		
EPA	0.025 (7)	
5. Carbon tetrachloride		
NAS	14 (1); 2.0 (7)	4.5 µg/L for 10^{-6} cancer risk, calculated by EPA from NAS-supplied figures
EPA draft SNARL	0.2 (1); 0.02 (10)	0.4 µg/L for 10^{-6} cancer risk, calculated by EPA from EPA (CAG) figures
6. Catechol		
NAS	2.2 (1)	
7. Chlordane		
EPA (draft)	0.063 (1); 0.008 (10)	0.023 µg/L for 10^{-6} cancer risk
8. Chlorobenzene		
EPA		72, non-cancer effects, calculated from EPA Water Quality Criteria
9. Chloroform		
NAS	22 (1); 3.2 (7)	
10. Dibromochloromethane		
NAS	18 (1)	

(continued)

TABLE B-13 (Continued)

	Short-Term Dose in mg/L (Days)	Long-Term Dose (Chronic) in ug/L
11. 1,2-Dibromo-3-chloropropane, or DBCP		
EPA		0.050, non-cancer effects; 0.01, for 10^{-6} cancer risk
12. 1,2-Dibromoethane, or Ethylene Dibromide, or EDB		
NAS		9.1×10^{-6} per μg/L, or 0.055 μg/L for 10^{-6} cancer risk, calculated
13. 1,4-Dichlorobenzene		
EPA		130, non-cancer effects, calculated
14. Dichlorofluoromethane		
NAS	350 (1); 5.6 (7)	
EPA	100 (1); 43 (10)	1600, non-cancer effects, calculated
15. 1.2-Dichloroethane		
NAS		7.0×10^{-7} per ug/L, or 0.71 μg/L for 10^{-6} cancer risk, calculated
EPA		0.95 μg/L for 10^{-6} cancer risk, calculated
16. 1,1-Dichloroethylene		
EPA (draft)	1.0 (1)	70, non-cancer effects
17. cis-1,2-Dichloroethylene		
EPA (draft)	4.0 (1); 0.4 (10)	
18. trans-1,2-Dichloroethylene		
EPA (draft)	2.7 (1); 0.27 (10)	
19. Di-n-butyl phthalate		
EPA		38.5 non-cancer effects, calculated from NAS ADI

(continued)

TABLE B-13 (Continued)

	Short-Term Dose in mg/L (Days)	Long-Term Dose (Chronic) in ug/L
20. Di-(2-ethylhexyl)phthalate, or DEHP		
EPA		210, non-cancer effects, calculated from NAS ADI
21. 2,4-Dichlorophenol		
NAS		700, non-cancer effects
22. 1,4-Dioxane		
EPA	0.020 (10)	
23. Epichlorohydrin		
NAS	0.84 (1) 0.53 (7)	
24. Ethylene glycol		
EPA (draft)	19 (1)	5500, non-cancer effects
25. Formaldehyde		
EPA (informal)	0.030 (1)	
26. Hexachlorobenzene		
NAS	0.03 (7)	2.9×10^{-5} cancer risk per μg/L
EPA		0.35, non-cancer effects, calculated by EPA from NAS ADI
27. Hexachlorophene		
EPA		0.35, non-cancer effects, calculated from NAS ADI
28. n-Hexane		
EPA (draft)	12.9 (1); 4.0 (10)	
29. Isopropyl alcohol		
EPA	1 (1); 1 (10)	
30. Methylene chloride, or Dichloromethane		
NAS	35 (1); 5.0 (7)	
EPA	13 (1); 1.3-1.5 (10)	150, non-cancer effects

(continued)

TABLE B-13 (Continued)

	Short-Term Dose in mg/L (Days)	Long-Term Dose (Chronic) in μg/L
31. Methyl ethyl ketone, or MEK		
EPA (draft)	7.5 (1); 0.750 (10)	
32. Methyl methacrylate		
EPA		35.0 non-cancer effects, calculated from NAS ADI
33. Polychlorinated Biphenyls, or PCB		
NAS	0.35 (1); 0.05 (7)	
EPA	0.001 (30)	
34. Styrene		
EPA		1300, non-cancer effects, calculated from NAS-supplied figures; 46.5, non-cancer effects, calculated from NAS ADI
35. Tetrachlorethylene		
NAS	172 (1); 24.5 (7)	20, non-cancer effects; 1.4 x 10^{-7} cancer risk per μg/L, or 3.5 μg/L for 10^{-6} cancer risk, calculated from NAS figures
EPA	2.3 (1); 0.175 (10)	3.5 μg/L for 10^{-6} cancer risk, or 0.9 μg/L for that risk, or 0.9 μg/L for that risk, calculated from EPA (CAG) figures
36. Toluene		
NAS	420 (1); 35 (7)	340, non-cancer effects
EPA	1 (1); 1 (10)	
37. 1,1,1-Trichloromethane		
NAS	490 (1); 70 (7)	3800, non-cancer effects
EPA		1000, non-cancer effects
EPA, calculated using NAS data	140 (1); 20 (10)	1.1, non-cancer effects

(continued)

TABLE B-13 (Continued)

	Short-Term Dose in mg/L (Days)	Long-Term Dose (Chronic) in μg/L
38. Trichloroethylene		
NAS	105 (1); 15 (7)	4.5 for 10^{-6} cancer risk, calculatd
EPA	2 (1); 0.2 (10)	75, non-cancer effects; 4.5 for 10^{-6} cancer risk, or 2.8 for that risk, calculated from EPA (CAG) data
39. Trichlorofluoromethane		
NAS	88 (1); 8 (7)	
EPA	25 (1); 2.2 (10), calculated from NAS data	
40. Vinyl chloride		
EPA		1 for 10^{-6} cancer risk, calculated from NAS data; 2 for that risk, if calculated from EPA (CAG) data
41. Xylenes (o-, m-, and p-)		
NAS	21 (1); 11.2 (7)	
EPA (draft)	12 (1); 1.4 (10)	620, non-cancer effects
EPA, calculation for m-Xylene only, using NAS data	6.1 (1); 3.2 (10)	

Abbreviations:

ADI - Acceptable Daily Intake
CAG - Carcinogen Assessment Group
NAS - National Academy of Sciences

TABLE B-14 MAXIMUM CONCENTRATION OF CONTAMINANTS FOR CHARACTERISTIC OF EP TOXICITY FOR RCRA HAZARDOUS WASTE (40 CFR, PART 261[a])

EPA Hazardous Waste Number	Contaminant	Maximum Concentration (Milligrams) Per Liter
D004	Arsenic	5.0
D005	Barium	100.0
D006	Cadmium	1.0
D007	Chromium	5.0
D008	Lead	5.0
D009	Mercury	0.2
D010	Selenium	1.0
D011	Silver	5.0
D012	Endrin (1,2,3,4,10,10-Hexachloro-1,7, epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo, ento-5, 8-dimethano naphthalene	0.02
D013	Lindane (1,2,3,4,5,6-hexachloro-cyclohezame, gamma isomer	0.4
D014	Methozychlor (1,1.1-Tricholoro-2, 2-bis [p-methozyphenyl] ethane)	10.0
D015	Toxaphene ($C_{10}H_{10}Cl_8$, Technical chlorinated camphene, 67-69 percent chlorine)	0.5
D016	2,4-D (2,4-Dichlorophenoxyacetic acid)	10.0
D017	2,45-TP Silvex (2,4,5-Trichlorophenoxypropionic acid)	1.0

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[a] EP refers to the RCRA Extraction Procedure. A waste is found to meet the EP Toxicity Characteristic if any contaminant in the extract (1:20) exceeds the maximum concentration listed.

TABLE B-15. INTERIM LIMITS ON METAL APPLICATION TO AGRICULTURAL SOILS[a]

	Soil Cation Exchange Capacity		
Element	0-5	5-15	> 15
Cadmium	5	10	20
Copper	125	250	500
Lead	500	1,000	2,000
Nickel	50	100	200
Zinc	250	500	1,000

[a] Maximum accumulative amount of metal which can be added to privately-owned farmland (kg/ha).

Adapted from: Ryan, J.A. "Factors Affecting Plant Uptake of Heavy Metals from Land Application of Residuals." In: Proceedings of the National Conference on Disposal of Residues on Land, September 13-15, 1976, St. Louis, Missouri. Sponsored by U.S. Environmental Protection Agency, Environmental Quality Systems, Inc. and Information Transfer, Inc., Rockville, Maryland.

TABLE B-16. REPORTED LEVELS OF SELECTED ELEMENTS IN SOILS

Element	Concentration in soil (µg/g)	Reference
Arsenic	5 average	1
	6 common	2
	0.1-40 range	2
	May reach several hundred ppm in soils overlying deposits of sulfide ores	
Aluminum	Ubiquitous in soil; as high as 40,000 ppm in some Great Plains soils	3
	Availability extremely low in soils with pH > 5.0	
Boron	10 common	2
	2-100 range	2
Cadmium	0.06 common	2,4
	0.01-7 range	2
Chromium	100 common	2
	5-3,000 range	2
	50-170	3
	1,000 in serpentine soils	3
Cobalt	8 common	2
	1-40 range	2
	<1 extractable	3
Copper	20 common	2
	2-100 range	2
	0.2-3.2 extractable	3
Iron	20,000-50,000	3
	1-100 extractable	3
Lead	10-30	3,5
	10 common	2
	2-200 range	2
	60 and 275--reported mean rural levels	6
Manganese	850 common	2
	100-4,000 range	2
	1-47 available	3

(Continued)

TABLE B-16. (Continued)

Element	Concentration in soil (μg/g)	Reference
Mercury	<0.01 to 4.6 for soils in western U.S.; mean 0.083	3
	0.147 mean for eastern U.S.	3
Molybdenum	2 common	2
	0.2-5 range	2
	0.1-0.3 available in southeastern Montana soils	3
	Elevated levels may occur in alkaline soils with high water table	3
Nickel	40 common	2
	10-1,000 range	2
	30	7
	5-40	3
Selenium	0.5 common	2
	0.1-2.0 range	2
Vanadium	100 common	2
	20-500 range	2
Zinc	50 common	2
	10-300 range	2
	5,000	8

REFERENCES FOR TABLE B-16

1. NRC. Arsenic. Committee on Medical and Biological Effects of Environmental Pollutants, National Academy of Sciences, Washington, D.C., ISBN 0-709-02604-0, 1977.

2. Ryan, J.A. "Factors Affecting Plant Uptake of Heavy Metals from Land Application of Residuals." In Proceedings of the National Conference on Disposal of Residues on Land, September 13-15, 1976, St. Louis, Missouri. Sponsored by U.S. Environmental Protection Agency, Environmental Quality Systems, Inc., and Information Transfer, Inc., Rockville, Maryland.

3. Munshower, F.F. "Microelements and Their Role in Surface Mine Planning." In Coal Development: Collected Papers, Volume II. Papers presented at Coal Development Workshops in Grand Junction, Colorado and Casper, Wyoming. Sponsored by Bureau of Land Management, July 1983.

4. U.S. Environmental Protection Agency. Scientific and Technical Assessment Report on Cadmium. Environmental Protection Agency, EPA-600/6-75-003, March 1975.

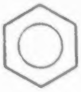
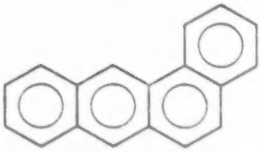
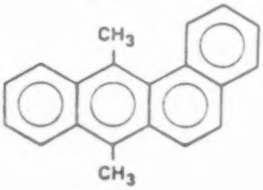
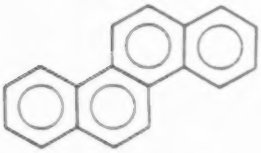
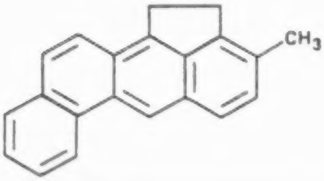
5. NRC. Lead in the Human Environment. Committee on Lead in the Human Environment, National Academy of Sciences, National Research Council, Washington, D.C., 1980.

6. Drill, S., J. Konz, H. Mahar, and M. Morse. The Environmental Lead Problem: An Assessment of Lead in Drinking Water from a Multi-Media Perspective. Prepared by MITRE Corporation for U.S. Environmental Protection Agency, Criteria and Standards Division. PB-296 556, May 1979.

7. NRC. Nickel. Committee on Medical and Biological Effects of Environmental Pollutants, Division of Medical Sciences, National Academy of Sciences, Washington, D.C., ISBN 0-309-02314-9, 1975.

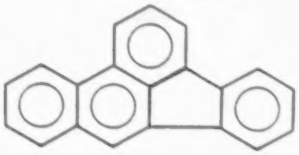
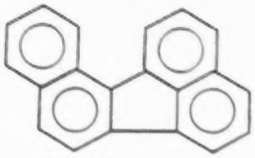
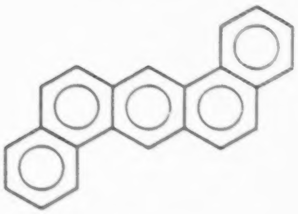
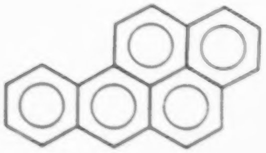
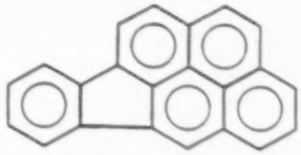
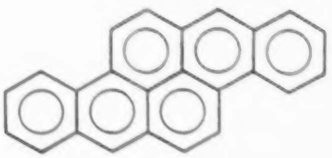
8. NRC. Zinc. Committee on Medical and Biological Effects of Environmental Pollutants, National Academy of Sciences. Prepared for the U.S. Environmental Protection Agency, Washington, D.C., EPA-600/1-78-034, May 1978.

TABLE B-17. SUBSTANCES WITH DESIGNATIONS BASED ON CARCINOGENICITY

Chemical Group	Substance Name and Structure	Specific Agency Designations
Hydrocarbons		
Simple aromatic	Benzene 	IARC (sufficient evidence in humans, carcinogenic for humans) NTP List EPA CAG List (risk assessment document prepared) EPA 1980 Water Quality Criterion (reflects carcinogenic risk) OSHA (special regulations reflect cancer hazard) ACGIH (industrial substance suspect of carcinogenic potential for man) NCI List (substance found to cause cancer in man)
Polycyclics		EPA 1980 Water Quality Criterion (reflects carcinogenic potential of polynuclear aromatic hydrocarbons)
	Benz(a)anthracene 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List
	7, 12-Dimethylbenz(a)anthracene 	EPA CAG List (six references cited)
	Chrysene 	EPA CAG List (Note: IARC determined that evidence of carcinogenicity is not sufficient)
	3-Methylcholanthrene 	EPA CAG List (three references cited)

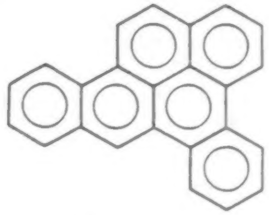
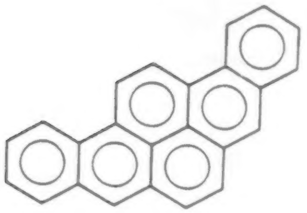
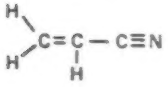
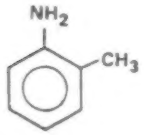
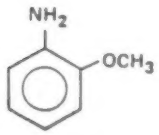
(continued)

TABLE B-17 (Continued)

Chemical Group	**Substance Name and Structure**	**Specific Agency Designations**
Hydrocarbons (continued)		
Polycyclics (continued)	Benzo(b)fluoranthene 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List
	Benzo(j)fluoranthene 	NTP List EPA CAG List (Note: IARC determined that evidence of carcinogenicity is not sufficient)
	Dibenz(a,h)anthracene 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List
	Benzo(a)pyrene 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List ACGIH (industrial substance suspect of carcinogenic potential for man)
	Indeno(1,2,3-c,d)pyrene 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List
	Dibenz(a,h)pyrene 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List

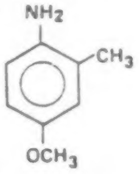
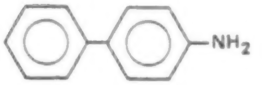
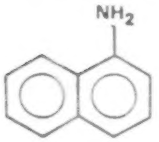
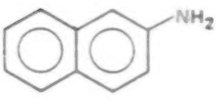
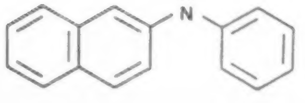
(continued)

TABLE B-17 (Continued)

Chemical Group	**Substance Name and Structure**	**Specific Agency Designations**
Hydrocarbons (continued)		
Polycyclics (continued)	Dibenz(a,e)pyrene 	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List
	Dibenz(a,i)pyrene 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List
Nitriles	Acrylonitrile  $H_2C=CH-C\equiv N$	IARC (sufficient evidence in animals; limited evidence in humans; probably carcinogenic in humans) NTP List EPA CAG List (risk assessment document prepared) EPA 1980 Water Quality Criterion (reflects carcinogenic risk) OSHA (special regulations reflect cancer hazard) ACGIH (human carcinogen)
Aromatic amines		
Primary	2-Aminotoluene (o-Toluidine) 	IARC (sufficient evidence in animals as the hydrochloride; should be regarded, for practical purposes, as if it presented a carcinogenic risk to humans) NTP List EPA CAG List NCI (evaluated as carcinogenic as the hydrochloride)
	1-Amino-2-methoxy benzene (o-Anisidine) 	IARC (sufficient evidence in animals as the hydrochloride; should be regarded, for practical purposes, as if it presented a carcinogenic risk to humans)

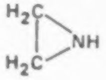
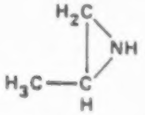
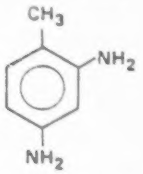
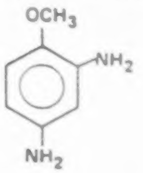
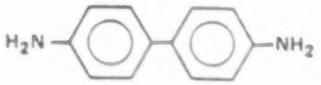
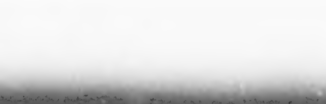
(continued)

TABLE B-17 (Continued)

Chemical Group	Substance Name and Structure	Specific Agency Designations
Aromatic amines (continued)		
Primary (continued)	4-Methoxy-2-methylaniline (p-Cresidine) 	IARC (sufficient evidence in animals; should be regarded, for practical purposes, as if it presented a carcinogenic risk to humans) NTP List NCI
	4-Aminobiphenyl (p-Xenylamine) 	IARC (sufficient evidence in humans and in animals; carcinogenic for humans) NTP List EPA CAG List OSHA (special regulations; labeled as "cancer suspect agent") ACGIH (human carcinogen) NCI List (substance found to cause cancer in man)
	1-Naphthylamine (α-Naphthylamine) 	EPA CAG List (risk assessment document prepared pertaining to technical grade 1-Naphthylamine) OSHA (special regulations; labeled as "cancer suspect agent")
	2-Naphthylamine (β-Naphthylamine) 	IARC (sufficient evidence in humans and in animals; carcinogenic for humans) NTP List EPA CAG List OSHA (special regulations; labeled as "cancer suspect agent") ACGIH (human carcinogen) NCI List (substance found to cause cancer in man)
Secondary	N-Phenyl-2-naphthylamine 	ACGIH (industrial substance suspect of carcinogenic potential for man)

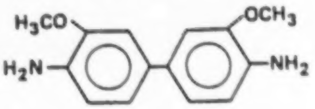
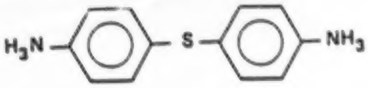
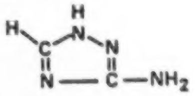
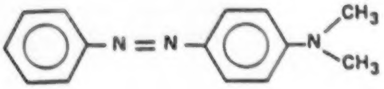
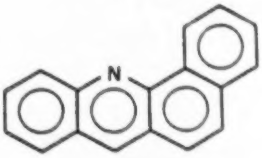
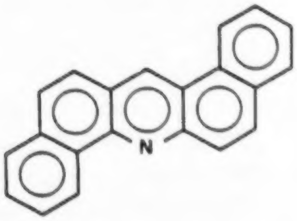
(continued)

TABLE B-17 (Continued)

Chemical Group	Substance Name and Structure	Specific Agency Designations
Aromatic amines (continued)		
Imines	Ethylenimine (Aziridine) 	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List OSHA (special regulations; labeled as "cancer suspect agent")
	Propylenimine (2-Methylaziridine) 	IARC (sufficient evidence of carcinogenicity in animals) ACGIH (industrial substance suspect of carcinogen potential for man)
Diamines	2,4-Diaminotoluene 	IARC (sufficient evidence of carcinogenicity in animals) NTP List
	2,4-Diamino-1-methoxybenzene (2,4,-Diaminoanisole) 	IARC (sufficient evidence of carcinogenicity in animals as the sulfate; should be regarded, for practical purposes, as if it presented a carcinogenic risk to humans)
	Benzidine (4,4' Diaminodiphenyl) 	IARC (sufficient evidence in humans and in animals; carcinogenic for humans) NTP List EPA CAG List (risk assessment document prepared) EPA 1980 Water Quality Criterion (reflects carcinogenic risk) OSHA (special regulations; labeled as "cancer suspect agent") ACGIH (human carcinogen) NCI List (substance found to cause cancer in man)
	3,3'-Dimethylbenzidine (o-Tolidine) 	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List ACGIH (industrial substance suspect of carcinogenic potential for man)

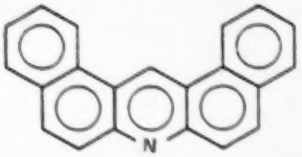
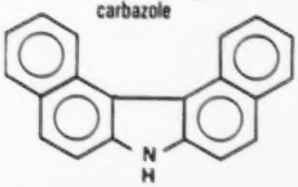
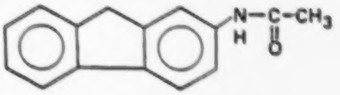
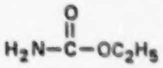
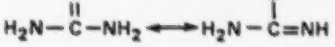
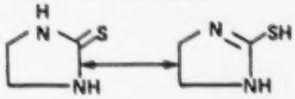
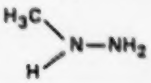
(continued)

TABLE B-17 (Continued)

Chemical Group	Substance Name and Structure	Specific Agency Designations
Aromatic amines Diamines (continued)	3,3'-Dimethoxybenzidine (o-Dianisole) 	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List
Diamine with sulfur	4,4'-Thiodianiline 	IARC (sufficient evidence of carcinogenicity in animals)
Azo compounds	3-Amino-1,2,4-triazole (Amitrole) 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List ACGIH (industrial substance suspect of carcinogenic potential for man)
	p-Dimethylaminoazobenzene 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List OSHA (special regulations; labeled as "cancer suspect agent")
N-Heterocycles Polynuclear	Benzo(c)acridine 	EPA CAG List (Note: IARC determined that evidence of carcinogenicity is not sufficient)
	Dibenz(a,h)acridine 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List

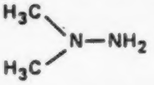
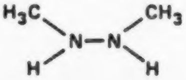
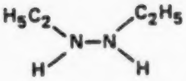
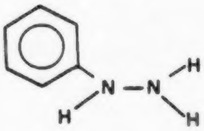
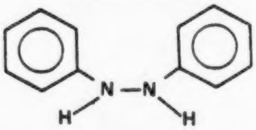
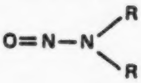
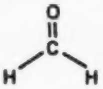
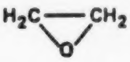
(continued)

TABLE B-17 (Continued)

Chemical Group	Substance Name and Structure	Specific Agency Designations
N-Heterocycles (continued)		
Polynuclear (continued)	Dibenz(a,j)acridine 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List
	7H-Dibenzo(c,g)-carbazole 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA List
Amides	2-Acetylaminofluorene (N-2-Fluorenyl-acetamide) 	NTP List EPA CAG List (ten references cited) OSHA (special regulations; labeled as "cancer suspect agent")
Ester-amide	Urethane (Ethyl carbamate)  $H_2N-\overset{\overset{O}{\Vert}}{C}-OC_2H_5$	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List
Thioamides	Thiourea (Thiocarbamide)  $H_2N-\overset{\overset{S}{\Vert}}{C}-NH_2 \longleftrightarrow H_2N-\overset{\overset{S}{\vert}}{C}=NH$	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List
	Ethylenethiourea 	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List
Hydrazines	Hydrazine H_2N-NH_2	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List ACGIH (industrial substance suspect of carcinogenic potential for man)
	Methylhydrazine 	ACGIH (industrial substance suspect of carcinogenic potential for man)

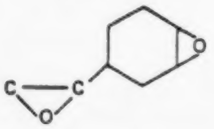
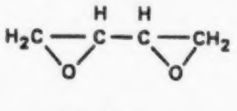
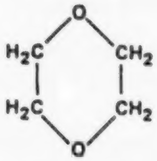
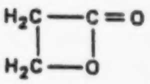
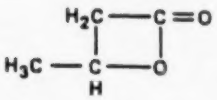
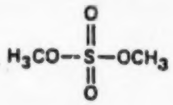
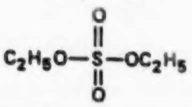
(continued)

TABLE B-17 (Continued)

Chemical Group	Substance Name and Structure	Specific Agency Designations
Hydrazines (continued)	1,1-Dimethylhydrazine 	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List ACGIH (industrial substance suspect of carcinogenic potential for man)
	1,2-Dimethylhydrazine 	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List
	1,2-Diethylhydrazine 	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List
	Phenylhydrazine 	ACGIH (industrial substance suspect of carcinogenic potential for man)
	1,2-Diphenylhydrazine (Hydrazobenzene) 	NTP List EPA CAG List EPA 1980 WQC (reflects carcinogenicity) NCI
Nitrosamines	Several aliphatics 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List EPA 1980 Water Quality Criteria (reflects carcinogenic risk) OSHA (special regulation for nitrosodimethylamine which is labeled as a "cancer suspect agent")
Compounds With Oxygen		
Aldehyde	Formaldehyde 	NTP List EPA CAG List ACGIH (industrial substance suspect of carcinogenic potential for man)
Epoxides	Ethlene oxide 	IARC (limited evidence in humans; probably carcinogenic for humans) EPA CAG List ACGIH (industrial substance suspect of carcinogenic potential for man)

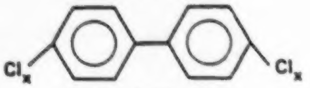
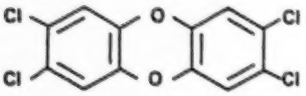
(continued)

TABLE B-17 (Continued)

Chemical Group	Substance Name and Structure	Specific Agency Designations
Compounds With Oxygen (continued)		
Epoxides (continued)	Vinylcyclohexene dioxide 	ACGIH (industrial substance suspect of carcinogenic potential for man)
	Diepoxybutane 	IARC (sufficient evidence of carcinogenicity in animals) EPA CAG List
Cyclic ether	1,4-Dioxane 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List NCI (evaluated as carcinogenic)
Lactones	β-Propiolactone 	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List OSHA (special regulations; labeled as "cancer suspect agent") ACGIH (industrial substance suspect of carcinogenic potential for man)
	β-Butyrolactone 	IARC (sufficient evidence of carcinogenicity in animals)
Compounds With Sulfur		
Organic sulfates	Dimethylsulfate  $H_3CO-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-OCH_3$	IARC (sufficient evidence of carcinogenicity in animals) NTP List EPA CAG List ACGIH (industrial substance suspect of carcinogenic potential for man)
	Diethylsulfate  $C_2H_5O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-OC_2H_5$	IARC (sufficient evidence of carcinogenicity in animals)

(continued)

TABLE B-17 (Continued)

Chemical Group	**Substance Name and Structure**	**Specific Agency Designations**
Selected Chlorinated Organics	Polychlorinated biphenyls (PCBs)  (two or more chlorine substituents on phenyl groups)	IARC (sufficient evidence in animals; probably carcinogenic in humans) NTP List EPA CAG List (risk assessment document prepared)
	2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) 	IARC (evidence of carcinogenicity in animals reported; evaluation is incomplete) NTP List EPA CAG List
Inorganics	Antimony trioxide (Production)	ACGIH (industrial substance suspect of carcinogenic potential for man)
	Arsenic (Inorganic compounds)	IARC (sufficient evidence in humans; limited evidence in animals; carcinogenic for humans) NTP List EPA CAG List (risk assessment document prepared) EPA 1980 Water Quality Criterion (reflects carcinogenic risk) OSHA (special regulations reflect cancer hazard) ACGIH (trioxide production—industrial substance suspect of carcinogenic potential for man) NCI List (substances found to cause cancer in man)
	Asbestos (All types of fibers)	IARC (sufficient evidence in humans and in animals; carcinogenic for humans) NTP List EPA CAG List (risk assessment document prepared) EPA 1980 Water Quality Criterion (reflects carcinogenic risk) ACGIH (human carcinogen) NCI List (substances found to cause cancer in man)
	Beryllium (Metal, oxide, sulfate, chloride, fluoride, hydroxide, carbonate, phosphate, silicate)	IARC (sufficient evidence in animals; probably carcinogenic for humans) NTP List EPA CAG List (risk assessment document prepared) EPA 1980 Water Quality Criterion (reflects carcinogenic risk) ACGIH (industrial substance suspect of carcinogenic potential for man) NCI List (substances found to cause cancer in man)

(continued)

TABLE B-17 (Continued)

Chemical Group	Substance Name and Structure	Specific Agency Designations
Inorganics	Cadmium (Metal, chloride, oxide, sulfate, sulfide)	IARC (sufficient evidence in animals; probably carcinogenic for humans) NTP List EPA CAG List (risk assessment document prepared) ACGIH (oxide production—industrial substance suspect of carcinogenic potential for man) NCI List (manufacturing exposures in cadmium using industries identified with carcinogenic effects in exposed people)
	Chromium (Chromates, chromate production)	IARC (sufficient evidence in humans and in animals; carcinogenic for humans) NTP List EPA CAG List (risk assessment document prepared) ACGIH (certain water insolubles—human carcinogen; chromates of lead and zinc—industrial substances suspect of carcinogenic potential for man) NCI List (substances found to cause cancer in man—chromates)
	Lead (Acetate and phosphate)	IARC (sufficient evidence in animals) NTP List
	Nickel (Metal, carbonyl, cyanide, sulfide, oxide, carbonate, nickelocene, refining)	IARC (sufficient evidence in animals; probably carcinogenic for humans) NTP List EPA CAG List (risk assessment document prepared) NCI List (manufacturing exposures in nickel refining identified with carcinogenic effects in exposed people) ACGIH (nickel sulfide roasting—human carcinogen)
	Selenium sulfide	EPA CAG List NCI (evaluated as carcinogenic)
	Uranium	NCI List (substance found to cause cancer in man due to radiation)
Nonspecific Chemical Substances	Coal tar pitch volatiles	OSHA ACGIH (human carcinogen)
	Coke oven emissions	NTP List EPA CAG List (risk assessment document prepared) OSHA (special regulations reflect cancer hazard) NCI List (substance found to cause cancer in man)

(continued)

TABLE B-17 (Continued)

Chemical Group	Substance Name and Structure	Specific Agency Designations
Nonspecific Chemical Substances (continued)	Creosote	EPA CAG List NCI List (substance found to cause cancer in man)
	Soot, tars, and mineral oils	IARC (sufficient evidence in humans and in animals; carcinogenic for humans) NTP List EPA CAG NCI List (substances found to cause cancer in man—soots, tars, cutting oils)
	Shale oils, asphalts, pitches, high boiling petroleum oils, various combustion products	NCI List (substances found to cause cancer in man)

✡U.S. GOVERNMENT PRINTING OFFICE: 1986-646-116/40633